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Cattins River

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THE

BUILDING MATERIALS

OF OTAGO

AND

SOUTH NEW ZEALAND GENERALLY.

BY

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PAPERS ORIGINALLY READ AT THE OTAGO INSTITUTE
REVISED AND EXTENDED.

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PREFACE.

DURING the progress of the Public Works under my charge, I have frequently been at a loss to know what material was best suited for the work in hand, and to what uses the local materials could be best applied. There were also frequent differences of opinion as to the identity of many articles, and continual differences as to their properties. This led me to collect and note any authentic information on the subject I met with. These notes grew into the Papers originally read at the Otago Institute, and the Papers have in turn expanded into the volume now published. If it is found to contribute in the slightest degree towards the development of the natural resources of the Colony, I shall be amply rewarded for any trouble it has cost me.

W. N. BLAIR.

DUNEDIN, 14th JUNE, 1879.

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BUILDING MATERIALS

OF OTAGO.

Introductory.

ANY information we have on the building materials of Otago is so interspersed with extraneous matter that it is comparatively useless. Even the initiated, whose duties require frequent reference to the subject, have considerable difficulty in availing themselves of the researches that have been made. The object of these papers is to present, in a concise form, the more valuable portions of the information already published, as well as to record my own observations and experience during the past few years. As some of the earlier information is not quite trustworthy, I have endeavoured to confirm all statements of facts by recent investigations. I do not, however, wish the papers to be considered exhaustive, or entirely free from errors; on the contrary, they only claim to be an introduction to a thorough investigation of the subject, which is

one of the utmost importance to the Colony at large. Although considerable care has been taken to avoid mis-statements, it is quite possible such may exist, and I look to my professional brethren and the members of the Otago Institute for their correction.

The natural resources of New Zealand generally, are equal to those of many old countries that take a prominent position in the affairs of the world, and, although Otago seems deficient in some of the products which are usually calculated to ensure prosperity—such as bituminous coal and metals—there is an abundant supply of good building materials of every description, and, with the exception of one or two articles, they are well distributed throughout the Province. Although I believe these papers will reveal a number of new facts, the researches that I have made in compiling them enable me to say, without reservation, that our resources are still practically unknown. Many of the best supplies are untouched, and, in all probability, *the best* of each kind is not yet discovered. It will, therefore, be many years before the extent of our resources in building materials is known, or the properties of even what has already been discovered, thoroughly understood. A still longer time must elapse before our stores are developed and utilized—this can only be effected by the increase of settlement and wealth, and improved facilities for transit. Although these causes are daily acquiring strength, they cannot exert a direct influence on the question till the cost of producing the native article comes nearer that of the imported one.

The importance that is attached to the collection and diffusion of knowledge of this kind throughout the colony was on one occasion forcibly brought under my notice by seeing in the newspapers that it was proposed to build the Auckland docks of Aberdeen granite. Undoubtedly granite is the best building stone in existence, but it is also the dearest, and for this purpose it is no better than the stone of which the Port Chalmers dock is built. The price of granite in rough blocks at Aberdeen is from 2s. 6d. to 3s. per cubic foot, and in London from 4s. 6d. to 5s. There are no regular traders between Aberdeen and Auckland that could carry the stone in small quantities, and no large ship would take a full cargo to come direct, consequently the shipment must be made at London. The cost of the stone in the Colony cannot therefore be less than 7s. per cubic foot. Port Chalmers stone in the same state can be put on board a coasting craft or steamer for 1s. 6d. Taking the freight and other charges the same as from London, we have the stone landed at Auckland for 3s. 6d. per cubic foot—exactly half the price of granite; and there would also be a considerable saving in labour, as the Colonial stone is much easier worked. The importation of granite under these circumstances is carrying the principles of free-trade a little too far.

There was no time in the history of New Zealand when the choice of a building material had so much importance as the present. To borrow the plan adopted by ethnologists, we may divide Colonial architecture into periods or ages: First, the wattle-and-dab period, with its contemporaneous but

more advanced varieties of fern-tree and totara-bark; second, the timber period; and third, the masonry period. On the gold-fields, timber is preceded by calico and corrugated iron. The Colony is now in a state of transition between the timber and masonry periods; we are exchanging the frail and ephemeral, for the strong and enduring. It is therefore our duty to spare no pains in selecting the materials that are most conducive to health and comfort, and that will remain for generations a record of our skill, forethought, and good taste.

In treating of the Building Materials of Otago, I shall consider the subject under the following heads :—*First*, Stones, Bricks, Concrete, and Roofing Slates; *Second*, Limes, Cements and their Aggregates; *Third*, Timbers; and *Fourth*, Metals.

SECTION I.

STONES, BRICKS, CONCRETE AND ROOFING SLATES.

CHAPTER I.

Description of Building Stones.

Classification.

BUILDING stones are usually divided into three classes, determined by their composition—viz., Silicious, Argillaceous, and Calcareous. Although this is, perhaps, the most natural and distinct classification that can be adopted, it is objectionable as bringing together stones of very different characters. For instance, granite and sandstone in the first class, and porphyry and clay-slate in the second. I purpose, therefore, to consider them under two heads, with the conventional names of *Hard Stones* and *Free Stones.*

Properties of Building Stones.—Before proceeding to treat in detail the individual members of these classes, it would be well to consider the pro-

perties of building stones generally, with special reference to the causes that lead to decay, and the means of preventing it. The principal bases of stone are silica, alumina, and lime. As can readily be inferred from the most superficial knowledge of these earths, the hardest and most durable stones are those in which the former predominates; many of them, such as granite and basalt, being practically indestructible. The building stones most subject to decay are sand and limestones. In the former it is caused chiefly by the mechanical action of winds, rains, and frosts, and in the latter by these and chemical agencies combined. Sandstone is composed almost entirely of silica or quartz grains or dust, cemented together by lime, alumina, magnesia, or iron; and sometimes by a combination of two or more of these minerals. As the particles of quartz are, like the stones already mentioned, practically indestructible, the durability of sandstone depends entirely on the cementing material. When this is nothing but alumina or clayey matter, the stone is of an inferior quality, that base being deficient in adhesive properties, and generally soluble in water. The stone is therefore peculiarly susceptible to the action of the weather. The presence of an undue preponderance of clayey matters in sandstone may frequently be detected by washing small pieces in water. Craigleith sandstone, the best in Great Britain, contains:—

Silica	98.3
Carbonate of Lime	1.1
Iron, Alumina	0.6
	100.0

Caversham stone, on the other hand, contains :—

Silica	24.4
Carbonate of lime and magnesia ...	53.0
Alumina	17.6
Soluble clay	1.5
Oxide of iron	1.4
Water and loss	2.1
	100.0

The reddish sandstones generally contain iron in considerable quantities; when the iron is naturally in a low state of oxidation, the stone has a tendency to decay on exposure. Changes from wet to dry seem to prevent rather than assist the cementing process. But when the iron is highly oxidised, and the whole a perfectly homogeneous and compact mass, the stone is not affected by the changes of the weather, and may therefore be taken as durable.

Sandstone is deposited under water, and hardened by pressure and drying, consequently it has a distinct natural bed. The stone is often of such a uniform colour and consistency that the lines of stratification are quite invisible, and as the stratum may not have retained its originally horizontal position, the mere inspection of a specimen in a museum, or of a block in a quarry, will not give the bed of the stone. It is, however, easily determined by the quarrymen from the facility of working in a particular direction.

As a general rule, sandstones are hardest and most compact when formed at the lower side of a thick stratum, or in the vicinity of basaltic dykes, or other volcanic rocks that may have disturbed them. The facilities for drainage afforded by the lie of the adjoining land has also considerable influence on the con-

sistency of the softer sedimentary rocks. In building with stones from stratified rocks, it is absolutely necessary that they be laid on their natural bed. A disregard for this rule is the sole cause of decay in a large majority of cases where buildings have failed. When the stones are placed in an inclined position, they afford the greatest facility for absorbing moisture; and, when vertical, the superincumbent weight has a tendency to split them. The latter evil is often greatly aggravated by a practice that exists among masons of working the beds slightly hollow so as to ensure a neat joint. The appearance of some of our soft-stone buildings fully bears out the above remarks as to the necessity of laying stones on their natural bed; some of them are smooth and solid after many years' exposure, while others, from the same quarry, and under exactly the same conditions, are in an advanced state of disintegration. This state of affairs could be prevented by simply marking the stones in the quarries where the lines of stratification are easily determined, and generally well-known. Independently of the increased durability, it is advisable to lay all stones on their natural bed, for they are a fourth stronger in that position than in any other.

Calcareous stones are less subject to decay from the mechanical action of the weather than sandstones, but are more susceptible to chemical agencies. As the cementing material is always the same, the durability depends entirely on the aggregates, and the proportions in which they are mixed. The compact and crystalline limestones are believed to be unstratified, consequently they are not liable to

exfoliation, and may be used in any position; but some of the softer kinds give indications of having been deposited in horizontal layers, in which case it is necessary to build with the stone on its natural bed. Although limestone is generally more compact than sandstone, it absorbs more water; but, on the other hand, the water affects it much less than sandstone. The compactness of limestone seems to keep the water from freezing, and so neutralizes its most powerful disintegrating property. All the softer limestones are hardened by exposure to the atmosphere; at the same time the atmosphere contains the elements of their destruction. The indurating process is not, as is sometimes supposed, attributable to the absorption of carbonic acid from the atmosphere, like the setting of mortar. The lime in the stone, being already a carbonate, cannot in this way absorb more of the acid. The hardening on exposure is caused entirely by the evaporation or drainage of the moisture contained in the pores of the stone.

The ingredients in the atmosphere that have the most deleterious effect on stones are muriatic and sulphuric acid, both of which have an affinity for lime, and combine readily with it, thus rendering the stone soluble in water. The former acid is always present in the atmosphere near the sea, and the latter in manufacturing towns where coal is burnt. All the softer limestones are more or less subject to the pernicious effects of both these acids, and when magnesia enters into their composition they are particularly susceptible to the action of sulphuric acid. The English Houses of Parliament are built of mag-

nesian limestone from the Bolsover quarries in Derbyshire, its composition being as follows :—

Silica	3.6
Carbonate of Lime	51.1
Carbonate of Magnesia	40.2
Iron, Alumina	1.8
Water and Loss	3.3
	100.0

It is well known that this stone has been a decided failure; the buildings were not many years finished when they began to show symptoms of decay. This result is due entirely to the sulphuric acid with which the smoky atmosphere in London is impregnated. The selection of the Bolsover stone for such an important work is perhaps the most curious instance on record of the miscarriage of skill, experience, and good intention. The English Government, fully alive to the necessity of having the Houses of Parliament built of the best stone procurable, appointed a Scientific Commission for the purpose of enquiring into the qualities of the various building stones in Great Britain. The Commissioners were men of the highest standing, whether as regarded their disinterestedness or scientific attainments; they had *carte blanche* to examine, enquire into, and experiment on every stone in the Kingdom; in short, their instructions appear to have simply been—select the best. After a long, laborious, and expensive investigation, and with the best possible intentions, the Commissioners selected "the magnesian limestone or dolomite of Bolsover," and it has turned out one of the most worthless stones for the purpose in Great Britain. The sole reason for this untoward result is in the

fact that at that time the peculiar affinity of magnesian lime for sulphur was unknown, and the Commissioners had the strongest possible proof of the durability of the stone in Southwell Minster, where it had withstood the action of the weather for 800 years. This was, however, in the pure air of a small country town—a condition that differs materially from that which the material occupied when exposed to the smoky and acidulous atmosphere of the metropolis.

Tests.—Except in rare cases, such as the arches of a long-spanned bridge and the lower courses in a spire or chimney, the pressure on stones in a building never approaches their crushing weight; their cohesive properties may therefore be disregarded in a popular investigation like the present one. I shall, however, consider shortly the proofs or tests of durability that should be observed in building with freestones.

Generally speaking, the hardest, heaviest, and least absorbent stones in a class such as sand or limestone, are the best; but this is no criterion when comparing classes. In sandstones the chemical test is the maximum amount of silica and minimum of alumina; the proportions of the other ingredients being within certain limits apparently of no consequence. The best limestones are those that approach nearest the crystalline state. Uniformity of tint and homogeneity of structure are also favourable indications. So far as strength and beauty, as well as durability under ordinary circumstances, are concerned, the magnesian limestones are best when the lime and magesia are in equal

proportion. This, however, as already shown, seems the worst proportion for a smoky town.

The absorbent properties of stones can be tested by subjecting them to the action of water under a slight pressure. With 14 lb. on the square inch, English Sandstones absorb from one-seventh to one-fourth of their entire bulk; Limestones, one-ninth to one-fifth; Oolites and Dolomites, one-fifth to one-fourth. The resistance of stone to disintegration can be tested by what is called Brard's process. This consists in boiling specimens in a solution of sulphate of soda (glauber salts), and afterwards dipping them at intervals into the cold solution for a few days. The action of this salt closely resembles that of frost, and Mon. Vicat has calculated that the effect after two days' application is equal to the force exerted by frost at 21deg. Fahr. on wet stone. The hardest granite is segregated by Brard's process in thirty days.

Artificial Induration.—The artificial induration of building stones is a problem that has occupied the attention of scientific men for years, and numerous processes have been tried with varying degrees of success. All the earlier experiments were confined to oils and bituminous matters, but these have, in most cases, proved more liable to decay than the stone they were intended to preserve. Latterly, the means of preservation have been sought for in acids and solutions that form new chemical combinations calculated to arrest and resist the progress of decay. Silicate of potash, chloride of calcium, and other compounds of a similar character, have been used in various ways with considerable suc-

cess, and it is thought that through such agency a perfect remedy will ultimately be discovered—a very great desideratum when the relative cost of building in hard and soft stone is considered. It seems to me, however, that there will always be a difficulty in applying the indurating fluid in the most effective manner. If it is simply spread on the vertical face of a building with a brush, as is usually done, it is not only apt to be washed off by rain, but it cannot possibly penetrate any great distance into the stone, which is thus covered with a hard skin liable to peel off. A liquid might be forced into the heart of the stone by hydraulic pressure before being placed in the building, but in all probability the power required to do so would impair its cohesive properties; and the cost of the process would necessarily be considerable.

CHAPTER II.

Geographical Distribution.

Localities.

THE geography of the Otago building stones comes more properly under the consideration of the Provincial Geologist, and is clearly shown on Professor Hutton's map.* It is, however, necessary, for the completeness of this paper, that a general indication of the localities be given.

Commencing with the older rocks, we have true

* Geology of Otago, 1875.

granite in mass at Preservation Inlet, and in numerous veins and isolated blocks in Stewart's Island, and along the whole of the West Coast. Syenite and other granite rocks are also found in large quantities in the same localities; and the Bluff Hill is chiefly composed of the former. Gneiss, mica schists, and other crystalline rocks of a similar character, which compose the Manipori formations, abound from Preservation Inlet to Martin's Bay, and inland to Manipori and the Te Anau Lakes. Schists and clay-slates exist in the Wanaka formation, a broad zone extending from the Taieri Plain and Waikouaiti to Lake Wanaka, and which is flanked on each side by narrower belts of the newer slates, and possibly limestones of the Kakanui formation. Although the two groups last mentioned are generally the repositories of the most valuable metallic lodes, they are the least productive in building stones. Roofing slates and a few varieties of limestones and marbles are, however, found in them. The Kakanui or Carboniferous formation comes next in order. It extends in a narrow strip parallel to the schists and clay slates, from Balclutha, via Switzers and the Eyre Mountains, to Martin's Bay. There are also large areas between the Big River and the Monowai Lake, at Orepuki, Stewart's Island, and the Upper Waitaki; with small patches at the Bluff, the Takatimos, Akatore, and the Horse Range. The Triassic, otherwise Maitai and Putaki formations, occupy the whole of the country between the Clutha and Mataura as far inland as Gore, thence extending in an irregular chain to the Takatimo range. The Waipai or Cretaceous

formation is represented in this Province by a strip of limited area extending from Shag Point to Otepopo, and a small patch at Mount Hamilton. The Oamaru, Pareora, and Wanganui series corresponding to the Eocene, Miocene, and Pliocene of geological chronology, occupy portions of the coast from the Clutha to the Waitaki, including the Waitaki Plain. The Maniototo Plain, Ida Valley, Manuherikia Valley, and the Tokomairiro Plain, all belong to this group, and an irregular belt of the same runs from Orepuki to the head of the Te Anau Lake. The economic products of the Pleistocene Formation are chiefly clays, gravels, and sands, which will be considered further on. The volcanic rocks of Otago yield valuable building materials, and are situated chiefly between Saddle Hill and Waikouaiti, but there are isolated patches at Aparima, Waihola, and Upper Taieri, and also between Shag Valley and Oamaru.

Products of Geological Formations.

Adopting Professor Hutton's numbers and classification of the Otago rocks, the following table gives the industrial products of the various formations :—

No	Age.	Formation.	Products.
1	Pleistocene ...	Pleistocene ...	Clays, Shingles, Gravels, and Sands.
2	Pliocene ...	Wanganui	Clays, Shingles, Gravels, Sands, and Limestones, Building Stones, Brown Coal, Cement Stones or Septaria.
3	Upper Miocene	Pareora	
4	Upper Eocene	Oamaru	

No.	Age.	Formation.	Products.
5	Cretaceous ...	Waipara ...	Marble, Limestones, Flint.
6	Jurassic ...	Pukitaka	Sandstones and Limestones for building purposes, Hydraulic Limes, Coal, and Ironstone.
7	Triassic ...	Maitai	
8	Carboniferous	Kaikorai	Best Sandstone for building purposes, Marbles, Limestones for mortar, Ironstones, Lead Ore, True Coal, Bitumen, Shale, and Fire Clay.
9	Silurian	Kakanui Wanaka	Roofing—Slates, Flagstones, Minerals, Ores of Tin, Copper, and Lead.
10	Laurentian ...	Manipora ...	Marble, Serpentine, Metals and Precious Stones.
11	Eruptive	Basalt Trachyte Granite	Building Stone, Road Metal, Pozzolanas and other Natural Cements, Sulphur, Borax, and Precious Stones.

CHAPTER III.

Hardstones.

THE hardstones suitable for building purposes in Otago are—

First. True, granite and syenites, with their varieties: syenitic or hornblendic granite and pegmatite or congealed granite.

Second. Metamorphic rocks: gneiss, clay-slates, schist, and quartz rock.

Third. Volcanic and trap rocks: basalt, bluestone, greenstone, dolomite, phonolite, timarzite,

breccia, and trachytes, with an endless variety of intermediate links and gradations.

Granites.

Granite is the monarch of building stones; although hard and tough, it is not difficult to work with the hammer, pick, or chisel. It can be got in any sized blocks, and takes a polish like marble. Granite has been used for centuries in engineering works and other structures, that are calculated to last for ages, but it is only of late years that it has been extensively used for ordinary architectural purposes. The introduction of stone-cutting and dressing machinery into the granite quarries has given this branch of the trade a great impetus, and it is possible that within a few years granite will supersede freestone in the more important public buildings of large cities.

True Granite.—According to Professor Hutton, Preservation and Chalky Inlets are the only localities in the Province where true granite is found in mountain masses, but it exists in large veins and blocks in Stewart Island and the whole of the West Coast. Professor Black, in Stewart Island, and Dr. Hector, on the West Coast, report its occurrence at every step. In appearance, the Preservation Inlet granite is not unlike that found in the Island of Mull. It is of a pinkish tinge, with grey spots, and rather coarse in the grain. Although, in all probability, it is equal in strength and durability to most of the granites of the old country, and consequently suitable for kerbing, paving, and engineering purposes, its colour will be

an objection in architectural works. I have no doubt our supply of granite for monumental and architectural purposes will ultimately come from the veins and blocks that are so profusely scattered in the various localities above-mentioned. Some specimens already obtained are most beautiful in colour, fine in the grain, and otherwise admirably adapted for the best class of work. There is a vein of light grey granite at Seal Island, the colour of which is uniform and agreeable; it has a white ground and dark spots, and the grain is very smooth. Similar veins of clear white granite, with spots of brown mica, have been found at George Sound. In one sample the mica is in mere specks, but in the other the mineral appears in large lustrous flakes. Both are extremely beautiful, and seem capable of taking a fine polish; but it is possible the latter, from an excess of mica, would lose its appearance in an exposed situation.

Syenite.—Syenite, as you are aware, differs from true granite, only in so far as it contains hornblende instead of mica. As mica and felspar are considered the perishable ingredients in these rocks, the durability of syenite can never be questioned. It is also, on the whole, tougher and more compact than ordinary granite. This stone is found in various localities on the West Coast and in Stewart Island, but the chief supply now available for industrial purposes is at the Bluff. Practically, the whole of the Bluff Hill consists of this material. It could therefore scarcely be in a more accessible situation. the Bluff syenite is hard and compact, and of a uniformly bluish grey tint of great beauty; conse-

quently, it is suitable for kerbing, paving, and massive masonry, as well as monumental and architectural works. In my opinion this stone is little, if anything, inferior to the famous Aberdeen granite, and I have no doubt the quarrying and dressing of it will, ere long, become an important industry.

There is a curious variety of syenite found at Milford Sound, the body colour of which is a pure opaque white, interspersed with oblong rectangular blotches of dark grey and black; these blotches are occasionally an inch long by three-eighths of an inch in breadth.

Another vein of syenitic granite exists at Isthmus Sound. The grain is rather coarse, but the colour, which is of a uniformly grey tint, is very good.

Pegmatite.—Pegmatite, or compact granite, is found at Milford Sound and Paterson Inlet. The former is of a grey tinge, with large spots of silvery-white mica of great brilliancy. This is perhaps the most beautiful stone in Otago, but it is doubtful if its appearance would be permanent out of doors. The stone at Paterson Inlet has a pinkish ground, with grey spots, and is much coarser in the grain.

When the utilitarian appetite of the colonist has been satisfied, and he has means and leisure to bestow on the ornamental, the beauties of the West Coast granites will no doubt be highly appreciated.

Constituents.—Although the stones above described vary much in appearance, there is little difference in their composition, and they are all embraced in the generic name of granite. All granitic rocks are composed of felspar, quartz, mica,

and hornblende, and the variety is determined entirely by the number of ingredients that it contains, and the proportions in which they are mixed. An undue preponderance of mica and felspar in granite, particularly when the latter is alkaline, is supposed to render the stones liable to loss of colour and to decay, but with that exception, granite of all kinds is practically imperishable. I have compared Mr. Skey's analysis of the Otago granites with that of the European varieties given in "Juke's and Geikie's Geology," and Professor Hull's "Building and Ornamental Stones," and find that, though at opposite sides of the globe, their composition is practically the same; the essential constituents in all cases being as follows:—

Silica ...	...	From 60 to 75	per cent.	
Alumina	...	„ 12 to 16	„	„
Oxides of Iron	...	„ 2 to 6	„	„
Lime ...	...	„ 2 to 5	„	„
Alkalies	...	„ 4 to 10	„	„

Metamorphic Rocks.

The second class of hard stones, forming the metamorphic rocks, is comparatively valueless as a building material—a few of the connecting links between them and granite, being of a crystalline texture, might be utilised; but as gneiss proper and the harder kinds of schist are composed of the granitic constituents in a stratified form, they will neither break nor cut across the grain, consequently can only be used in rough work. Much of the masonry on the Otago Goldfields is composed of schist, notably the piers of the Cromwell bridge, and the houses in the Teviot District. Although somewhat coarse and irregular, the work is by

no means unsightly. There are several crystalline stones of the metamorphic formations of Otago that seem suitable for ornamental purposes. Granulite, of a light grey colour and fine grain, has been found at Breaksea Sound. Syenitic gneiss, of a grey flaky appearance, exists at "Connecting Arm," and brownish gneiss at Anchor Harbour. These all appear capable of being dressed or polished into columns or slabs for monumental purposes. The slates in this series of rocks should yield paving stone. It is reported that such exist at Chalky and Preservation Inlets on the West Coast, but I have no particulars regarding them.

Volcanic and Trap Rocks.

Varieties.—It is from this class that the principal supply of hard stone is at present obtained, therefore the fullest information on its products and their properties is of the utmost importance. So far as varieties are concerned, it is quite impossible to give even an indication of their extent. Although the area occupied by these rocks is comparatively limited, the building stones they yield are simply confusing in their profuseness. They comprise every texture and colour from the black basalt that yields to nothing softer than diamond, to white tufa that can be sliced with a pocket-knife. Generally all compact stones of volcanic origin are durable, and, being unstratified, there is no danger in using them in any position. As already stated, eruptive rocks are found in several localities in the Province, but so far as I am aware the Peninsula and the district between Otago Harbour and Blueskin Bay

are the only places that produce the trachytes, breccias, phonolites, and other stones of so varied a character. There are few rocks of economic value outside this area except the ordinary blue and greenstones.

Basalts.—Commencing with the hardest, we have black basalt and basaltic conglomerates at the Bluff, Dog Island, Purakanui, and Taiaroa Head, and various other places on the Peninsula, so hard that more steel than stone is removed in dressing them. They are therefore comparatively useless as building material, so it is unnecessary to consider them further.

Bluestone.—Bluestone, which is so largely used for road metal and ordinary rubble masonry, is to be found in almost all districts that have been disturbed by volcanic agencies. Sometimes, it exists only in bombs and small columns, fit for nothing but road metal and pitching; but at other times, it occurs in large dykes, that yield valuable building stones.

The best quarries in the Province are those in the Dunedin Town Belt, the valley of the Leith, and Ross Creek. The most of the bluestone used in Dunedin comes from those quarries. It forms excellent rubble, and with a little labour, picked ashlar; but it is altogether too hard for chiselled work. The basements of nine-tenths of the buildings in Dunedin are built of bluestone rubble, and many important edifices, such as St. Paul's Church, the Wesleyan Chapel, Knox Church, the Mercantile Agency Store, and the residences of the two Bishops, are built of coarse hammer-dressed rubble, with facing of lighter coloured materials, the effect of which is very pleasing.

Greenstone.—Greenstone is simply bluestone, in a more tractable form, and is used for much the same class of work. There is, however, no supply near the centres of population, so its use hitherto has been comparatively limited. Greenstone is found in the Mataura Valley, on the shores of Lake Wakatipu, and at Greenhills, in Southland; its colour varies from light green to dark red.

Dolerite.—Dolerite is a dark grey, or brownish stone, of vesicular texture, and harder, but more brittle, and easier worked than bluestone. It is usually found near volcanic centres, associated with the other basaltic rocks; it is quarried for road metal at Waihola and Tokomairiro. A small vein that yielded building stone, now exhausted, was at one time worked near the top of York Place. The base of the Colonial Bank, one of the finest pieces of massive masonry in the Province, is chiefly built of dolerite from this quarry. A large reef of this rock occurs at Timaru, where it is extensively used for basements.

Phonolite.—Phonolite, or clinkstone, and porphyry, are found in Bell Hill. As they do not exist in large blocks, they are not suitable for massive masonry, but answer admirably for ordinary building, being easily worked; some of them are remarkably beautiful in colour and fine in texture, capable of being used for ornamental purposes. A polished block of phonolite in the Museum shows an arrangement and blending of various shades of grey colours that excels the best efforts of the grainer. The Gaol and some of the other old buildings in Dunedin are built of clinkstone, as well as several of the most

recent structures, notably Mr. Howden's house at Anderson's Bay.

Timarzite.—Timarzite, an eruptive rock found on the Peninsula, resembles closely the Bluff syenite in colour and consistency, the only difference being that the latter has a slight tinge of green, instead of blue, intermixed with grey. It seems adapted for both useful and ornamental purposes, but has hitherto been little used.

Breccias and Trachytes.—The breccias and trachytes, with their connecting links, come next in order, and they are the most important class of hard-stones in Otago. They exist in large quantities in the vicinity of Port Chalmers and throughout the Peninsula, and in most cases the quarries are easy of access by rail or water. The Port Chalmers stone, which was the first utilised, still holds the first place in point of strength and durability, and the facility presented for getting it in large blocks. It is, however, inferior to some of the others in colour and smoothness of grain, which are essentials in architectural work. The Port Chalmers stone is a true breccia of a bluish grey colour, with the rock fragments of all sizes, up to six inches. It is hard and tough, but yields readily to the pick. The Port Chalmers Graving Dock, one of the finest structures in New Zealand, is built entirely of this stone, the quarry from which it was obtained being within 200 yards of the work. All the kerbing used in Dunedin and Port Chalmers is from the same locality. Most of the quarries now worked yield stone of a fine texture, easily dressed, and altogether well suited for any architectural works of a

substantial character. Although the labour of rubbing this stone to a perfectly smooth surface is greater, there is not much difference between it and the hardest sandstone, when worked with the chisel and fine axe. Some good specimens of this class of work can be seen at the Mercantile Agency Store, the Union Bank, and Messrs. Sargood's Warehouse.

After that used at the Dock, the next good building stone discovered was at Sawyer's Bay. With the exception of colour, this stone is, to all intents and purposes, the same as the former. The colour is a light grey, about the same shade as Portland cement, but with a slightly orange tinge. In consequence of its lighter colour and the proximity of the quarry to the railway, this stone soon became a favourite in Dunedin. It has been extensively used, both as ordinary rubble and dressed ashlar work; the facing of St. Matthew's Church, Messrs. Ross and Glendining's warehouse, Messrs. Cargill's store, and a large number of private buildings are of this material. It may be interesting to note that the railway through Wales's quarry at Sawyer's Bay has revealed the fact that the white stone is only on the outside of the cliff. On penetrating a distance of 30 yards, the colour gradually changes to blue as found in the other quarries about Koputai Bay. On the other hand, the Deborah Bay tunnel, seven-eighths of a mile long, is almost entirely through Sawyer's Bay stone, the same colour, but much softer than in the quarry. It should be noted that the Sawyer's Bay stone does not retain its colour when exposed to the weather. Although

there is no symptom of decay, the stone in some of the older buildings is already considerably defaced by large stains.

The quarries and railway cuttings show that the breccia rock extends from Sawyer's Bay to the township of Mansford, a distance of nearly two miles, and from sea level to the top of the range at Lean's Rock, a height of 500 feet. The width inland is not known, but were it only a crust on the mountain side five hundred yards thick, it could produce stones sufficient to make a Liverpool of Docks in Otago Harbour, with a Glasgow in each of the other Provinces. The accessibility of the Port Chalmers stone is also worthy of notice. Two railways run through it at different levels, and the Harbour, with deep water at several places, skirts the foot of the rocks.

Breccia.—Breccia similar to that at Sawyer's Bay is found at Broad Bay, Castle Larnach, and several other localities in the Peninsula. With the exception of Castle Larnach, which is chiefly built of this material, the Peninsula stone has not yet been much utilised.

A breccia of much the same consistency, but of a beautiful brown colour, exists on the northern slope of Puketapu. It seems capable of taking a fine polish, and will probably be used for monumental purposes.

Another stone of the same colour, but finer in texture—possibly, a trachyte—is found in small quantities at Kakanui mouth, and in considerable reefs near the Taieri Lake. The Hamilton Road

Bridge—a substantial piece of masonry—is built of this description of stone found on the spot.

Trachytes.—The trachytes proper, as a class, furnish softer and easier-worked stones than the breccias; they are therefore more suitable for the ordinary purposes of the builder. There is a large assortment of trachytes on the Peninsula, and in the vicinity of Port Chalmers. Many of the deep cuttings on the Northern Railway between Port Chalmers and Blueskin pass through masses of this material. Tomahawk Valley produces a brown trachyte with bright orange spots: it is nct much harder than some kinds of sandstone, and seems capable of being easily dressed. Although rather dark for the whole front of a building, it might be introduced into some portions with great effect. The Port Chalmers trachytes are generally light in colour; one sample in the Museum is a delicate fawn of uniform tint and soft even texture. Those in the railway cuttings are of all conceivable colours and shades. I am not aware that either of the latter two has been utilized, but I have no doubt this could be done to advantage now that ready means of transit is provided. Some of the light coloured stone particularly should soon become popular in Dunedin, everything being so favourable to its use; it is easy of access, easily worked, and can be obtained in moderately large blocks; it has also every appearance of durability.

There is a peculiar looking trachyte or tufa at Harbour Cone, on the Peninsula, which, so far as consistency is concerned, should be classed with the freestones. Its colour is a light brown, with white

spots, and the texture is much the same as Oamaru stone, but with less grit in it. The stone dresses as easily as an ordinary sandstone, and has a handsome appearance with any kind of work—smooth dressed, chiselled, or picked. Although the chalky feel of its surface is a symptom of weakness, the class to which it belongs is a durable one, and it is therefore entitled to a fair trial. The steps at Larnach Castle are made of the Harbour Cone tufa in one length of eight feet. Although thus placed in the most trying situation, the stone is wearing remarkably well, and Professor Hutton says that soft trachyte is often as durable as basalt or bluestone. It has also the property of resisting fire, and on this account is used in building the lime kilns on the Peninsula. A stone somewhat similar to that at Harbour Cone is found in large quantities in Blueskin Bay, near the Township of Evansdale, and on the slopes below Merton. The latter, which is more of a basaltic conglomerate, has recently been used in building the piers of the Waikouaiti Road Bridge.

CHAPTER IV.

Freestones.

CLASSIFICATION. — The freestones of Otago are naturally subdivided into three classes :—*First*, Marbles; *Second*, Limestones; *Third*, Sandstones. As some of the trachytes and tufas just described might just as well be classed under the head of freestones, so, on

the other hand, might the marbles and crystalline limestones be included with the hardstones. It is, however, less confusing to let each be considered with the other members of its own family, although its character accords better with a stranger.

MARBLES.

The marbles of Otago are still, practically speaking, unknown and untouched; the information collected about them is meagre in the extreme; and the few known deposits have not yet been utilised. Some important discoveries of marble have however been made across the border—in Canterbury,—and a good deal has been done towards opening out quarries, and developing a trade in the stone. Although the Canterbury marbles cannot be classed in the Building Materials of Otago, they are intimately connected therewith; consequently, we may give them some little consideration.

Horse Range.—A grey variegated marble exists at the Horse Range, in considerable quantities; it has all the characteristics of a true marble, and seems equal in every respect to the imported samples of the same variety. It has not, however, been worked, and there is little known as to the extent of the seam.

Tokomairiro. — Professor Hutton reports the existence of a handsome black marble with shells, "somewhere near Tokomairiro," the exact locality being unknown. I have made numerous enquiries on the subject, but can find no information as to the position or extent of the deposit. The dis-

coverer is evidently not disposed to give particulars at present.

Otekaike.—A bed of light brown marble has been discovered on the property of the Hon. Robert Campbell, M.L.C., at Otekaike. It is of a fine even texture. The colour is rather dull by itself, but it would look well in contrast with others of more decided and brighter tints, or if relieved by gold figuring. The extent of the deposit is unknown.

Clyde.—Mr. Vincent Pyke, M.H.R., has sent me specimens of a beautiful white marble found on the eastern bank of the Clutha River, between Clyde and Cromwell. It occurs in a vein, the outcrop of which is about a foot square. The stone seems harder than ordinary European marble, and thin slabs are quite translucent, like alabaster.

West Coast.—Dr. Hector reports the existence of marble of various colours and consistency in several localities on the West Coast. In no case, however, did he find the rock *in situ*; the specimens were always taken from large isolated blocks and boulders. They comprise pure white and the common variety of colours, with others of a rarer description, such as white and green, specked with brown, and lead-coloured mica. The white is stated to be suitable for statuary; the samples in the Museum show the grain to be rather coarse and crystalline for this purpose; but in all probability this defect will not exist in stone from solid rock. The Hon. Capt. Fraser, M.L.C., has lately discovered this white marble "in the reef" at Annita Bay, Milford Sound. He has kindly given me the

following description of the stone, and the locality in which it occurs:—

"The Annita Bay marble, Milford Sound, discovered by me, is a saccharine marble, resembling the purest loaf sugar in colour and texture, working freely in any direction, and not liable to splinter. Some of it is slightly translucent and capable of taking a polish, but the greater part of it is too highly crystallized to be used for table-tops, &c. It works and rubs down to a smooth surface, and would be admirably adapted for pillars and ornamental architecture of every kind. The vein is twelve feet thick and about a hundred yards in length, and is immediately above high water mark. Blocks could be craned from the quarry to the vessel, as the water is deep alongside and nearly always calm."

Mr. Macfarlane, the Government Agent at Jackson's Bay, writes me that the small range enclosing Annita Bay seems to have been detached from the main one behind, and that it is much shattered, consequently it is possible that the solid reef at the shore may not be of great extent. He is, however, confident that the original deposit will be found in the main range.

One of the finest samples of New Zealand marble that I have yet seen comes from Caswell Sound. The ground colour is bluish white, with faint streaks and pencillings through it, of a darker tint of the same colour. The texture is soft, even, and perfectly homogeneous. So far as I can judge, it is equal to any European variety. The stone is found in a solid reef twenty feet thick, situated close to the water's edge, in the most convenient place possible for shipping. Steps are now being taken to utilize the Caswell Sound marble. I shall be very much surprised if its quarrying and working does not yet grow into an important industry.

From a geological point of view the localities on the West Coast just mentioned, as well as the carboniferous formations, are calculated to produce marbles of all kinds, so I trust they will ere long be thoroughly explored.

A connecting link between marble and limestone is found at Crooked Arm, in the stone called Cipollino. It has all the appearance of coarse-grained loaf sugar, interspersed with small brown specks. The stone is very beautiful, and seems sufficiently hard and durable for at least ornamental purposes indoors, but its general character as a building material is little known.

Canterbury.—Mr. Munro, of Dunedin, has opened up marble deposits at the Kakahu River, seven miles from Geraldine. There are two different kinds; one is of a delicate dove colour, with beautiful shadings, and the other is bluish green and white, in distinct markings. The texture in both cases is soft and even. The dove coloured rock is very much shattered, so large blocks of stone cannot be obtained; but the green variety exists in large masses. The extent of the marble deposits in the Kakahu District has not yet been determined.

The only marble quarries in New Zealand that have been fairly opened up with a view to permanent working are at Malvern Hills, in Canterbury. An influential company was formed in 1876 to work them, and since then considerable progress has been made in developing the enterprise.

The marble is found in reefs, in a conical hill about eight miles from the White Cliffs Railway

Station, the extent of the deposit being practically inexhaustible. There are two distinct varieties—the "Grey," and the "Imperial Red." The former has a bluish-black ground, with distinct white lines, the general effect being grey; the latter is of a mottled light red colour of a peculiarly rich tone, something like Peterhead granite. The grey reef yields blocks of twenty tons weight and upwards. The red one is not quite so solid; still, blocks can be obtained much larger than is required for ordinary building and ornamental purposes. A large quantity of the Malvern Hill marble—worked into slabs, columns, and ornaments of various kinds—is exhibited in Christchurch; they show that the stone is suitable for all the purposes to which European marble of similar colours is applied.

There is every prospect of a considerable export trade in the Canterbury marbles. Authorities in London have reported favourably of them, particularly the red. They compare it with the "Jaune Fleuri" marble of France, but say that the former is much more valuable. The red Canterbury marble is stated to be worth from 20s. to 30s. per cube foot in London against 12s. to 15s., the price of its European prototype. This difference is more than sufficient to turn the scale in favour of the Colonial article, and the price quoted shows that the trade is likely to be profitable.

Professor Bickerton's analysis of Canterbury marble shows it to be identical in composition with those in other countries. The sample analysed contained "98·53 per cent. of carbonate of lime, with an insoluble residue consisting of silica, alumina,

and manganese, the colouring matter being due to the latter constituent."

Limestones.

Classification.—The limestones proper are as varied in colour and consistency as they are great in numbers. They comprise every shade and hue, from dark grey and blue to pure white, and every texture and degree of hardness, from stone as hard as basalt to chalks and recent concretions that can be dug with a spade. There is often a difficulty in deciding as to whether certain stones should be called limestones or sandstones. Strictly speaking, they should be put in the class to which their predominant ingredients belong; but, like the purely chemical arrangement referred to at the outset, this brings unlikely relations together. For instance, Caversham stone is more than half lime, though it has all the appearance and attributes of a sandstone. The classification of doubtful specimens is therefore made on the general resemblance to their class, rather than on a chemical basis.

Wakatipu.—Again, commencing with the hardest and most compact, we have large masses of limestone at the Twelve Mile Creek, on Lake Wakatipu. In colour and texture they closely resemble ordinary green or bluestone, possibly a little softer, but every bit as tough. The rock seems shattered on the surface, and incapable of yielding anything but materials for rubble-work and ordinary ashlar: but it is probable that large blocks will be obtained when quarries are opened out. The stone has not yet been extensively used for building purposes; but its excellent quality, and the ease with which

it can be quarried and shipped, cannot fail to bring it into prominent notice. A further reference to this stone will be found in a subsequent chapter on Limes.

Horse Range.—A bluish-grey granular limestone is found associated with the marble in the Horse Range. So far as strength, durability, and appearance is concerned, it would make an excellent building material. It is found on the Shag Valley side of the range, but I have no information as to the accessibility of the rock or the size of the blocks attainable.

Peninsula.—There is a fine limestone in the Peninsula, darker in colour and harder, but closely resembling in general appearance the famous Bath stone of England. It has little or no grit, works freely, and seems durable. The colour is a peculiar tint of brown, rather sombre for building in a mass, but suitable for facings and monumental work. The stone exists in large quantities, and is procurable in moderately sized blocks. It should therefore become a popular building material when means of transit are provided. The deposit is in a very inaccessible situation, on the eastern side of the Peninsula, consequently the stone cannot be utilised at present.

Kakanui.—A hard, shelly, white limestone has recently been discovered at Kakanui, and used in some structures in that locality. It is of a uniform colour and consistency, nearly as hard as Sawyer's Bay stone, but much easier worked. It should prove a valuable addition to our stock of building materials. A variety of this stone from

the same place, similar in colour and consistency, but full of large fossil shells, has been quarried for the foundations of the new road bridge; it is admirably adapted for work of that kind, but is altogether too rough for architectural purposes. These stones are both procurable in large blocks, and the supply is unlimited.

Waiareka.—A coarse grey limestone, of uniform colour and consistency, is found in large quantities on the Totara Station, near the Waiareka Creek. With the exception of the foundations of the Waiareka road bridge, it has hitherto been little used. Although considerably more friable, the stone is about as hard as the Tasmanian sandstone; it has a beautiful warm tint of an agreeable shade, and seems capable of being dressed in any way from hammered to polished work.

Waihola.—A valuable addition to the limestones has recently been worked at Waihola Gorge in the shape of a beautiful grey stone found on the western side of the Main Road, about half a mile from the railway. The stone, when newly quarried, is harder than the Oamaru stone when dry, consequently it must be very much harder after being exposed to the air for some time. It can be dressed in any way, is capable of taking a fine polish, and, being easy of access, it cannot fail to become popular as a building material, when better known. A solid face of stone, 20 feet thick, is already exposed in the quarry, consequently the appliances for handling and transporting blocks must alone determine their size.

Both sides of the Waihola Gorge contain large

quantities of the limestone that is used for lime-burning. This is a very hard, compact stone of a beautiful white or light cream-colour without a speck. So far as strength, appearance, and durability are concerned, it makes good building stone, but hitherto it has not been found in blocks of sufficient size; the whole rock is shattered into layers a few inches thick.

Pleasant Valley.—The blue and grey limestones of Pleasant Valley come next in order. Several varieties of them exist in large quantities, and they are all remarkable for beauty and uniformity of colour, fineness of texture, and the ease with which they can be dressed and carved. Such of them as do not contain an undue proportion of clay—notably the yellowish grey varieties found near Tumai—have all the appearance of durability, but a great many are too soft and friable for out-door work. The Bank of New Zealand, Waikouaiti, built of a handsome blue variety, was only a few years in existence when the stone showed symptoms of weathering, and the arrises and mouldings are now worn quite away.

Oamaru Stone.—We now proceed to the consideration of the most important building material that hitherto has been utilised in Otago, viz., the Oamaru stone. The use of this material is coeval with the settlement of the district in which it occurs, but it was little known beyond till 1866, when an export trade commenced with Dunedin. The first large building erected of this stone in the city was the Otago University—now the Colonial Bank.

The Oamaru stone occupies that large tract of

country in the northern part of the Province, extending northward from the Kakanuis to the Waitaki Plain, and westward from the coast to the Kauroo River—an area altogether of about 100 square miles. The same class of stone is also found in the following localities:—Upper Waihemo Valley; Riverton, to the head of Te Anau Lake; Castle Rock, on the Taringtura Downs; Limestone Ridge, in Waimea Plains; and numerous places in Canterbury. Practically speaking, the supply of this material is inexhaustible. There are extensive quarries worked in the Oamaru district, from which a large quantity of stone is produced annually, both for local wants and export to other parts of the Colony and to Melbourne. The trade with the latter port is of recent birth, but it promises to be ultimately an important one.

The principal quarries now at work in the Oamaru district are at Cave Valley and Kakanui. The Town of Oamaru is chiefly supplied from Cave Valley, and Dunedin and other southern districts from Kakanui. The trade to Dunedin alone is sufficient to keep one or two vessels constantly trading to Moeraki.

Much has been said as to the relative merits of the Oamaru stone from different localities, but I do not think that there is any practical difference in similar samples. The constituents of the stone are almost the same throughout the Province, so any difference in colour or texture must be due to its proximity to foreign matter or facility of drainage.

The Oamaru stone, correctly speaking, is a white granular limestone. It has a remarkable unifor-

mity of colour and texture; not only can large blocks be got of the same tint and consistency, but whole cities might be built in which one stone could not be distinguished from another. According to Mr Skey, its component parts are—

Carbonate of lime	90·15
Alumina	1·55
Oxide of iron	·55
Soluble silica	·45
Insoluble matter	7·15
Loss	·15
	100·00

The ordinary English building stone which most resembles this is the Ketton Oolite, its analysis being—

Carbonate of lime	92·17
Do. magnesia ...	4·10
Iron and alumina	·90
Water and loss	2·83
	100·00

The weight of Oamaru stone, wet from the quarry, is 105 pounds per cubic foot, and when perfectly dry 92 pounds. That of the Ketton Oolite, when dry, 128 pounds. The lightest limestone in England is the Bath Oolite, which weighs 115 pounds per cubic foot. The New Zealand product is therefore the lightest by about 23 pounds per cubic foot.

Applying the chemical tests to the Oamaru stone we place it on a par with the oolites and common limestones of England and the Caen stone of France; and Professor Hutton in his "Geology of Otago" says, that it is "exactly similar to the limestone of Malta, of which the town of Valetta is built." According to Dr Hector,

the resistance it offers to the disintegrating action of glauber salts is comparatively feeble. Its inferiority to the above mentioned stones consists chiefly in its excessive porosity.

I have made several experiments with the view of measuring its absorbent powers, the results of which are worth recording. A block of selected Kakanui stone, used as a footstool in my office for seven years, and consequently thoroughly dry and hard, furnished the best possible materials for the tests. A piece of this stone, 7 inches square and $1\frac{1}{2}$ inches thick, equal to 73·5 cubic inches, weighing when dry 56oz. 17dwt. 11gr. troy, was put in water. Within forty hours, it had absorbed 12oz. 0dwt. 15gr., equal to 31 per cent. of its entire bulk, and 21 per cent. of its weight. The specimen was allowed to remain in the water for sixteen days, when the quantity absorbed had increased to 14oz. 2dwt. 19gr., which gives 36 per cent. of the entire bulk, or 228 gallons of water in a cottage wall ten feet square and one foot thick.

A bar of Oamaru stone 13 inches long and 1.65 inch square was next placed vertically in a glass of coloured water. It stood 3.2 inches into the liquid. In six hours the moisture was quite visible to the top of the bar, and in 12 hours the colouring matter had risen $7\frac{1}{2}$ inches. As the stone in both these experiments was particularly dry, the maximum results were probably obtained. But on the other hand, the vertical position of the bar in the second experiment was less favourable to the absorption of moisture than that usually occupied by stones in a building, particularly the horizontal parts of mould-

ings, cornices, copings, and window sills. It should be pointed out that the Oamaru stone absorbs 36 per cent. of its bulk without pressure, while the most porous English stone only absorbs 25 per cent. under a pressure of 14lbs. on the square inch. It is doubtful, however, if an increase of pressure in the former case would give corresponding results, the stone, being so excessively porous, gets completely saturated at once. When the dry samples were first put into water the air rushing from the pores of the stone caused bubbles to rise to the surface for fully ten minutes. The first experiment shows that the stone is capable of absorbing 10 lbs. per cubic foot more water than it contains when in the quarry, a result to me quite unexpected and not easily explained.

One of the most important points in connection with the use of Oamaru stone is the degree of induration it attains in drying, and the loss sustained by subsequent exposure to moisture. So far as the hardening is concerned, I am quite satisfied that the largest blocks used in ordinary masonry become equally hard throughout in a few months, and possibly in a few weeks, under the influence of a warm, dry atmosphere. The hardness is not confined, as is sometimes supposed, to a thin crust on the surface of the stone, but penetrates to the centre making the whole a perfectly homogeneous mass. In consequence of the time required, I have not been able to prove by direct experiment that a stone once hardened becomes soft on exposure to wet. I fear, however, that such is the case; the window sills and mouldings on the south side of

the Colonial Bank are now fully softer than when they left the quarry, and the chances are that these stones had acquired a considerable degree of hardness before being placed in the building. The cornice and parapet on Messrs Dalgety, Nichols, and Co.'s warehouse, although in a much more favourable situation—on the sunny side of the street—are softer still; the stone can be scratched out in handfuls by the finger nails. This is, however, one of the oldest, if not actually the oldest, piece of Oamaru stone masonry in Dunedin; it is, therefore, possible the material was bad to begin with.

Against these unfavourable examples, the bridge in Thames street, Oamaru, built in 1860, and several other buildings of the same age in that locality, are not decayed, nor unduly charged with moisture. The ultimate durability of our Oamaru stone buildings cannot, of course, be determined at this early stage of their existence, and any estimate short of actual trial is little more than conjecture. Professor Black might, however, give us his opinion as to whether it can long resist the action of the saline breezes from the Ocean Beach, the sulphurous fumes of the Green Island coal, and the other impurities that are now so rapidly accumulating in the atmosphere of Dunedin. I should be loth to prophesy evil, but if the durability of the Oamaru stone is to be measured by its power of resisting moisture, it is to be feared that the handsome spires and façades that now ornament the city will not transmit the names of their architects to many succeeding generations.

Although the bad qualities of the Oamaru stone are quite apparent, there is on the other hand, so

much to recommend it, that it will always be a popular building material. I shall therefore consider the works for which it is well adapted and the precautions necessary to ensure the best results from its use. The stone is well adapted for any ordinary work in a dry, warm climate like that of Victoria, and it is unexcelled for internal decorations of all kinds and in all situations. It is suitable for ecclesiastical architecture generally, and forms a beautiful contrast as facings to darker stone. It should not be used in the southern side of buildings, particularly if they are recessed, and it is altogether unfitted for window sills, parapets, and the upper side of large mouldings, and similar projections. Buildings of this material should be designed to have as few of these as possible, and where unavoidable, the flat tops of the stones might be covered with some preservative; from an æsthetical point of view, this is the only part of a stone building where such should on any plea be permitted, unless the preservative used is perfectly transparent. Dampness can be prevented to a certain extent by an impervious foundation, internal lining, hollow walls, and other expedients of a similar nature.

I have made several experiments with Oamaru stone to test the expediency of certain appliances occasionally used to prevent damp. A bar of dry stone, after receiving two coats of ordinary oil paint, was deposited in water. In 40 hours it had absorbed 34 per cent. of its bulk, including the weight of the paint, against 31 per cent. absorbed by unprotected stone in the same time. Another sample coated with soluble glass—the principal indurating

ingredient in artificial stone—absorbed 27 per cent., exclusive of the weight of the solution, which was 4 per cent. more. Although these experiments give an indication of the results to be derived from the application of the materials referred to, they are altogether too crude to be advanced as conclusive. The oil in the paint was absorbed to such an extent by the stone, that the colouring matter which remained on the surface could be washed off by water. It is therefore probable that much better results would be obtained by more coats, and the use of heavier pigments like red lead. With reference to the use of soluble glass as a remedy for damp, I am not sure that this is a property to which it lays special claim. Although porosity is a primary cause of decay, it may be possible to increase the hardness and durability of stone without removing the lesser evil. Besides, the method of applying the solution adopted by me may not be exactly correct.

The following is a recapitulation of the results obtained by the various experiments on Oamaru stone:

	Pounds per cubic foot.
Weight when fresh from quarry	105
„ „ quite dry	92
„ after 40 hours' immersion in water ...	111
„ „ 16 days' immersion in water ...	115
„ painted stone, after 40 hours' immersion in water, including paint	111
„ of stone coated with soluble glass, after 40 hours' immersion, including solution ...	111

The principal buildings, entirely of Oamaru stone, in Dunedin are the Colonial Bank, First Church and Manse, Union and New South Wales Banks, Fernhill, and the Pier Hotel. In Oamaru, nine-tenths of the buildings are of this material, and

several of them, such as the National Bank and the Star and Garter Hotel, are worthy of a place with the architecture of the Old World. The private residences in that district can also be classed along with the country houses of England, notably Windsor Park, Elderslie, Awamoa, Totara, and Otekaike; the latter, now approaching completion, is one of the finest houses in the Colony. Oamaru stone has also been used in numerous road and railway bridges, many of them of considerable span.

The above remarks on the quality of Oamaru stone, which appeared in the original papers, gave rise to a considerable amount of adverse criticism, and I was pressed to consider the subject further to see whether I could not modify my views and give the stone a more unqualified recommendation. I readily undertook the task, and have embraced every opportunity that presented itself of getting further information on the subject during the three years that have elapsed since the first paper was prepared.

So far as pointing out the valuable properties of the stone is concerned, it has probably not received full justice. On the other hand, its bad qualities have not been exaggerated. It is quite unrivalled for purposes of internal decoration. The ordinary freestones of the old world do not offer anything like the same facilities for the sculptor's art. The Oamaru stone carvings of studies in foliage, animals, and traceries of various kinds, by Mr Godfrey, of Dunedin, are not surpassed in chasteness of design or delicacy of manipulation by the works of the mediæval artists.

Professor Ulrich informs me that the subject of the induration of Oamaru stone was somewhat fully investigated in Melbourne, when it was discovered that the exposure of smoothly dressed samples to the action of a dry atmosphere resulted in the formation of a tolerably impervious and durable crust on the surface. The crust, which is exceedingly thin, is not supposed to form at all in a damp situation, where the growth of vegetation is faster than the indurating process; neither will it form a second time when once broken off. Any stone, therefore, that gets its upper edges injured is not much benefited by the hardness of the face; on the contrary, the imperviousness of the face accelerates decay, by retaining the moisture that comes in above. Still, with all these drawbacks, the discovery is a valuable one, inasmuch as it indicates that proper care in disposing and protecting Oamaru stone may materially enhance its value.

The decay in the Colonial Bank referred to in the original paper, is attributed to the stones having been subjected to the action of sea water during shipment at Oamaru and Moeraki. There is some ground for this conclusion, for the instances of decay in the district in which the stone is found are comparatively few, whereas they are common enough in Dunedin. It is not, however, certain that the particular stones that are decaying were subjected to the action of salt water; and further, it is questionable whether the water would have the effect of seriously disintegrating after such a lapse of years. If salt water is the cause of decay in this case, it only bears out my

former remarks as to the result to be anticipated from the continued action of the saline breezes of the Ocean Beach, combined with the smoky atmosphere of the city.

The Oamaru stone will not resist the action of frost. I observed some monuments of comparatively recent date in the Queenstown Cemetery fast falling into decay from this cause.

As my former experiments with reference to the absorbent powers of the Oamaru stone were challenged, I obtained, through the Oamaru Stone Quarrying Company, picked samples from the Weston Quarries. On subjecting them to the same treatment, I found that they absorbed almost the same quantity of water as the stone from the Kakanui quarries referred to in the original paper. The Weston stones were cut into blocks 8 inches long, 3⅓ inches broad, and 2 inches thick. One of them was coated with oil by Mr Munro of Dunedin, in the manner practised and recommended by him, another was thickly painted, and two were left unprotected. All the samples were placed together on edge in half an inch of water for eighteen hours, then totally immersed for eighteen hours, with the following results, which are the weights per cubic foot in the different conditions :

	Unprotected stone.	Oiled stone.	Painted stone.
Weight dry	95	93	94
,, after partial immersion	115	97	94
,, ,, total immersion	115	112	94½

In addition to confirming the accuracy of the former experiments on unprotected stone, these show that thorough painting renders the stone almost perfectly impervious, but that oiling is not so efficacious; further that the latter process is sufficient to resist damp arising from occasional showers, but not the action of protracted wet weather.

Upper Waihemo Valley.—There are two varieties of freestone in this locality, that may be classed with the Oamaru stone—one of a bluish grey, and the other a yellowish white colour.

The bluish variety is a hard, compact, fine-grained limestone of much the same consistency as the Craigleith sandstone. It comes hard from the quarry, consequently it cannot be worked with saws and other carpenters' tools like the Oamaru stone. It is, however, suitable for quoins, lintels, door-steps, and similar purposes, where little labour is required, and where hardness is an advantage. When struck with a metallic substance, this stone emits a peculiar sulphurous smell something like that of gas. The supply of the bluish stone is comparatively limited, and large blocks cannot be obtained.

The yellowish white variety, which I shall call "Waihemo Freestone," is a compact granular limestone, somewhat coarser in the grain and more gritty than Oamaru stone, but considerably harder and less porous. Its colour is a dull white with a yellowish or orange tinge of a soft and pleasant tone. The stone is very soft when quarried, so it can be turned and worked with carpenters' tools to any degree of ornamentation. It retains its softness for

a long time, but ultimately becomes excessively hard.

A complete analysis has never been made of the Waihemo freestone, but it is believed to be chiefly carbonate of lime, and a trace of carbonate of magnesia, with a small proportion of silica in the form of grains scattered mechanically through it. In all probability the colour is derived from a slight admixture of iron. This composition resembles that of the English Portland stone.

Although not very extensively used, the Waihemo freestone has acquired a high character for durability and the power to resist moisture. The Waihemo Hotel, built about 1862, and several station buildings in the neighbourhood of even earlier date, are still as fresh as when erected, and the stone has become very hard. I was particularly struck by the way in which the hotel doorstep had withstood the heavy traffic for such a long time. The buildings above referred to are all of rough stone; the only case in which there has been a trial of the stone in a dressed state is in Sir F. D. Bell's house at Shag Valley Station, erected in 1871-2. So far as can be judged from this short experience the result is likely to be satisfactory, there being no discolouration, neither the least appearance of weathering on the edges.

The Waihemo freestone when fresh from the quarries is very porous. I found it to absorb $17\frac{3}{4}$ pounds of water per cubic foot when partially immersed, and 22 pounds when fully immersed, for thirty days. It was tested alongside a sample of Oamaru stone of the same size, and except that the

latter took in the water somewhat faster, there was no practical difference in its effect on both. The Waihemo stone, however, gets hard and impervious on exposure in almost any situation, and there seems to be no limit to the process. The outcrop of the rock is nearly as hard as marble, and some of the stones in the older buildings seem to be gradually approaching that condition. The imperviousness also increases with age; the walls in Sir Francis D. Bell's house, already referred to, are quite watertight. From the peculiarity of the paper-hangings it is impossible for the least damp to come through the stone without being at once detected.

The supply of the Waihemo freestone is practically inexhaustible. The principal deposits occur in what is known as the Green Valley, about twenty miles from Palmerston. Quarries have been opened in several places very convenient for working, and blocks of a large size can be obtained.

Southland.—The granular limestone found in Southland belongs to the same class as the Oamaru stone. It exists in a broad zone extending across the country from the Mataura to the Waiau. The principal outcrops of the rock at present known occur at the Limestone Ridge on the Waimea Plain, Castle Rock in the Taringatura Downs, and the ranges in the Aparima, Mararoa, and Waiau valleys.

This, which I shall call the "Southland Stone," is a granular limestone of a yellowish white colour, much harder and heavier than the Oamaru stone, but coarser in the grain and not so good a colour. A sample from Aparima, analysed by Dr Hector, was found to contain—

Carbonate of Lime	...	...	92·20
Oxide of Iron ...	...	...	2·20
Insoluble matter	...	...	5·60
			100·00

This composition resembles that of some of the carboniferous limestones of Great Britain.

In consequence of its remoteness from the centres of population, the Southland stone is practically unknown as a building material. Its use has hitherto been confined to the erection of an occasional building on an up-country run. But there is now every chance of its being utilised, as the railways are fast penetrating into the districts in which it occurs.

I have made some experiments on the absorbing powers of two samples from the Castle Rock. One of them has been in my possession for three years, and the other was recently sent me by Mr Pratt, of Invercargill. They were both, however, freshly dressed at the time of testing. The same process was followed as in the case of the Oamaru stone just described, with the following results, the figures being the weight per cubic foot in the various conconditions :

Castle-Rock Stone.	Old Sample.	New Sample.
Weight dry	134	135
„ after partial immersion ...	139	143
„ „ total immersion ...	144	146

It will thus be seen that the Southland stone is one-half heavier to begin with than the Oamaru stone, and that it only absorbs about one-third the quantity of water when partially immersed, and one-half when

totally immersed. The Southland stone unprotected is far more impervious than the Oamaru one when prepared with oil. The imperviousness of the Southland stone has been well proved at the residence of Mr G. M. Bell, Waimea Plains. A nine-inch wall on the shady side of the house was papered on the bare stone, and the papering remained intact for six years.

Canterbury.—The low ranges on the eastern side of the main range throughout the whole length of Canterbury contain immense quantities of granular limestone, of various kinds. It has been used to a considerable extent in Christchurch and other places, but I am not aware of any investigation having been made as to its qualities and constituents.

Sandstones.

General.—The sandstones of Otago are as varied in consistency, and more numerous than the limestones, but excel them in diversity of colour. The extremes in the latter are generally connected by gradations of blue and grey, but sandstones merge into all conceivable shades and hues. As already stated, the Craigleith sandstone—the analysis of which has been given—is the best in Great Britain. It is, however, too hard for many purposes, so the Midland and Scotch stones that have 5 or 10 per cent. less silica may be taken as the type of a good and useful building material. A corresponding type in the Colonial product is found in the Tasmanian freestone, of which the High School, Custom House, and Cargill Monument are built; it contains 86 per cent. of silica. Any Otago sandstone that

has so much of this base and has a hard compact texture, may be considered strong, durable, and dry. The sandstones proper, which embrace all sedimentary rocks *in situ*, are found in immense quantities throughout the Province. Unfortunately, the more accessible supplies are of an inferior quality; consequently this stone has hitherto been little used for building purposes.

Grits.—The highest class of sandstones, as regards their relation with the hard stones, are grits. These abound throughout the Province, chiefly in the form of large boulders, or erratic blocks, like the Sarsen or Druid stones of the south of England. Numbers of them exist on the ranges about Blueskin, Kaikorai, North Taieri, Tokomairiro, and Kaitangata. They yield stone of a red or brownish colour that varies in texture from coarse sandstone to conglomerate with large pebbles. The blocks are usually harder than ordinary sandstone, but are sometimes wanting in cementing material, so much so that the stone easily reverts under pressure to its original gravel. The grits furnish good building material for massive coarse work, but are comparatively valueless for architectural purposes. The railway bridges at Chain Hills and Glenore are built of this kind of stone; that in the former work is comparatively fine in the grain, but the others are coarse and full of pebbles. They are both used in large blocks, which, along with the dark colour of the stone, tends to give the structures a massive appearance very appropriate to this class of work.

Silicious Sandstones.—Closely allied to the grits, and existing under much the same circumstances in the same localities, we have numerous fresh-

water sandstones. They are of various colours, but are all extremely hard and compact, apparently highly charged with silica. A very handsome stone of this kind, found in the Hillend district, has been used in the abutments of the Clutha Railway bridge; it is of a silver-grey colour, and of an even hard texture, resembling closely the Tasmanian stone. The same stone occurs again at Tapanui. It exists in masses sufficiently extensive to constitute a solid reef. Other samples, found in the Clutha and Chain Hills districts, are of a reddish-white colour and equally compact in texture. There is a good specimen of white sandstone in the Museum, from Murison's Gully, on the Rough Ridge; in all probability it belongs to this class.

The silicious sandstones above mentioned are too hard to be economically used in ornamental work, but they are unexcelled for plain masonry, and for all purposes where strength and durability are the principal desiderata.

A connecting link between the grit and sandstone proper is found on the western side of the Waihola Lake, from Mary Hill to the Gorge. It has a tough granular texture, capable of being easily dressed with the pick or chisel, but too hard for smooth work; its colour is a light warm brown, very suitable for architectural purposes. The stone is supposed to exist in large quantities, but has hitherto been little used. Mr Duff's house is the only building of it that I know.

Hard Sandstones.—The hardest sedimentary rocks are of course met with in the older geological formations, but deposits of a similar character frequently occur in recent formations—the induration

in the latter case being due to local causes. The Kaikoura, Maitai, and Pukitaka formation—the localities of which were given in a previous chapter—yield the former class, and the best known deposits occur between the Clutha and Mataura rivers. One of the hardest sandstones in Otago is that at the Falls at Gore township, and other places on the Mataura river. It is of a light green or bluish tint, almost as hard as bluestone, and equally unworkable. It is found in large blocks, with natural joints and beds, and so is very suitable for massive, coarse work. The two bridges over the Mataura are built of this material.

A similar stone—though scarcely so hard—is found on the Oreti river, at Benmore; it is utilised in Invercargill for basements of buildings. The same variety occurs again at the Kaihiku, the road bridge over that stream being built of it.

Waikava, as might be expected from the geological character of the district, produces a compact hard sandstone, suitable for building. The only sample in the Museum is rather dark for architectural purposes, but I have no doubt there is an abundant supply of all kinds between the Clutha and the Mataura. In 1865 Dr Hector said of this stone, "It has a disagreeable colour, but its texture and stability are superior to any of the sandstones in the Province which have as yet been examined, although others have been seen that will probably prove of quite as good quality." The Waikava sandstone contains 80 per cent. of silica, which is a near approximation to the Tasmanian stone in its essential constituents.

Mount Hamilton, in Southland, produces an excellent sandstone of much the same character as that of Waikava, but firmer in the grain, and of a bluish colour. Altogether this is a first-class building material, but I have no information as to the extent of the deposit or the facilities presented for working the stone.

The same remarks apply to a specimen of stone lately sent me from the Mataura district; the proprietor of the land would not, however, tell me the exact locality.

Hard sandstones from the older formations have been found at several places on the West Coast, notably Jackson's Bay. The Government Agent there, Mr. Macfarland, sent me a block of excellent quality and colour. He says that the supply is inexhaustible.

The hard sandstones of the recent formations are widely dispersed throughout Otago. One of the best deposits known is at Few's Creek, on Lake Wakatipu, where three distinct varieties occur, the respective tints being yellow, red, and green. The former, which is the most common, has been utilised at Queenstown for building and monumental purposes. It is hard and compact, and has a particularly smooth even texture. The deposit is located on the margin of the Lake, in a most convenient position for shipping.

Several varieties of hard sandstone found in the vicinity of Palmerston form excellent building materials, notably the dark grey stone used in the Presbyterian Church, and the bluish-grey one of which the road bridge is built. The former is found

in the Horse Range, and the latter on the northern slope of Puketapu. The last-named locality also produces a yellow stone, of much the same consistency; it is sometimes found in the same vein as the blue variety, and the two colours frequently merge into each other in a curious manner. There is a sample in the Museum of a smooth-grained dark red ferruginous stone from the Upper Horse Range, that belongs to this class of rocks.

The above are only quoted as examples of what the district referred to can produce. There are numerous places in the vicinity of the railway between Pleasant Valley and Trotter's Creek where good sandstone is obtainable. The whole range of country along the sea-board between the Waikouaiti and Kakanui Rivers contains an immense assortment of sandstone; many of them, like a portion of the cliffs in Trotter's Gorge, are too soft and friable for building stones, but there are a great number of isolated blocks and veins that yield good building materials of the kind just described.

Ordinary Sandstones.—Under this heading I shall consider the class of sandstones that come nearest in consistency to the popular definition of freestone—those that are so soft as to be easily worked and at the same time sufficiently hard to resist the action of the weather.

A hard brown sandstone of this description has recently been discovered and worked on the north side of the Otepopo Hill. It was used in lining the railway tunnel through that range. Although hard, the stone dresses readily with the axe. It is found in large blocks, with regular vertical cleavages in

both directions, at right angles to each other, which gives the stones two natural faces almost as true as can be worked artificially, thereby presenting great facilities for quarrying and dressing. The brown sandstone of Otepopo is too dull in colour for ordinary architectural work in large surfaces, but seems well adapted for basements, facings, and massive masonry.

The variety of ordinary sandstones that comes next under consideration is the rusty yellow varieties found at Anderson's Bay, Arden Bay, Kaikorai, Saddle Hill, and Greytown. Apparently these rocks are simply ordinary soft sandstone like that at Caversham—dried, consolidated, and baked by volcanic fires. In the early days of the settlement this stone was used to some extent in Dunedin and its vicinity. In the Jurors' Report of the New Zealand Exhibition, analyses are given of several varieties, which show them to have, to a moderate extent, the essentials of a good building material. The reporters, however, say that, in consequence of the excess of impalpable cementing matter contained in the Arden Bay stone, "it will not be durable if much exposed to the weather," and that the Anderson's Bay stone "breaks up rapidly when tested with sulphate of soda, so it will not resist the action of the frost." These two stones happen to have been used in the New Zealand Clothing Factory, built about the year 1861. From its enclosed position, the southern wall of this building never gets the sun, so the stone has been subjected to the severest meteorological test that can be applied in Dunedin. The predictions with reference to the Arden Bay stone

have been realised, as the lintels and sills are beginning to decay; but three lintels of the Anderson's Bay stone are as fresh as when erected.

The class of sandstone that comes next in order of hardness I shall call the "Otepopo Freestone," as that district furnishes the greatest number and variety of specimens. They however occur at other places throughout the Province, notably at Tumai and other places in the Waikouaiti district, and on Mr Larnach's property, near Broad Bay. In the Otepopo Valley the stone is of all shades—from clear white to dark yellows and reds. That at Mr. Larnach's is bluish-grey, like Portland cement. Although it abounds in great quantities, and often in accessible situations, the distances of the deposits from centres of populaticn or a shipping port has hitherto prevented its use; neither has the stone, to my knowledge, been analysed. It seems to have most of the attributes of a good building material, the only objectionable feature I can discern is an apparent deficiency of cohesion between the particles of sand. As the cementing ingredient does not appear to be clay or lime, it is possible this defect does not exist in stone from the bed rock. If the objcction just mentioned is not found to be a serious one, I have no doubt our main supply of freestone for architectural purposes will ultimately be drawn from the Otepopo freestones.

Soft Sandstones.—The lowest grade of freestones, and the last in my list, is the one represented by the well-known Caversham stone, a name which I shall apply to the whole variety. The deposit of this rock throughout the Province is practically unlimited.

It can be found anywhere along the coast, and for a considerable distance inland, from Kaitangata to Moeraki. The extent of the deposit in accessible situations increases the regret often felt about the inferiority of the stone, and one is apt to wish that it had exchanged places with the carboniferous sandstones in the neighbourhood of the Dome Pass or Eyre Mountains. This stone has been found below sea level at Green Island and Otago Harbour, and 1000 feet above it at the Leith Saddle; and the Look-out Point tunnel, 950 yards long, is through a solid rock of the same material—I might almost say a solid stone, for there are only five or six cracks in the entire length. The Caversham stone is generally of a bluish-grey or yellow colour, but these are seldom blended in any way. Its texture is also remarkably uniform. In peculiar situations, such as isolated cliffs, and near basaltic dykes, the stone occasionally changes, but the solid stratum of rock is perfectly homogeneous. Although it was extensively used as a building material some years ago, Caversham stone is allogether unsuited for any purpose where strength or durability is required. It does not at first harden on exposure like the limestones, but begins to decay whenever erected, if exposed to winds, rains, or frosts. Some of the Caversham stones used in old buildings that have been painted, are still sound; but there are few exposed examples, particularly on southern walls, that are not decayed to a considerable extent, and some of the older houses at Forbury are crumbling to decay with great rapidity.

Conclusion.

This completes a description of the principal Otago building stones on which I have information. It will be observed that although they comprise samples from all quarters of the Province, there are several isolated districts capable of producing good materials, to which no reference has been made, viz., the Upper Waitaki, Pomahaka, Switzers, and the Waiau. Their resources are practically unknown, consequently I am under the necessity of omitting them.

CHAPTER V.

Bricks.

Locality and Raw Materials.

THE materials for making Bricks are so widely and abundantly diffused throughout Otago, that the difficulty is to find a locality where they do not exist. Like many other native products, colonial bricks were for a long time held in great disrepute, and it was even thought impossible to produce a good article from the materials at command. There is not the slightest ground for this impression; on the contrary, the clays of Otago are, so far as I am able to judge, superior in quality to the English ones. In one respect their superiority is very marked—that is, in their freedom from stones and

gravel, which is such a drawback to the English brickmaker. The inferiority of the colonial article was caused entirely by want of care in selecting and preparing the clay, and insufficient burning.

Clay for ordinary bricks should not be too stiff and plastic on the one hand, or too friable and sandy on the other; neither should it contain an excess of lime, iron, or alkaline earths, although small quantities of these ingredients are, in certain circumstances, desirable. Bricks made of stiff, rich clay, shrink in drying, and crack and twist in burning; but this can be prevented by an artificial mixture of sand. If the clay is quite free from sand to begin with, about 20 per cent will be required to reduce its strength. When this proportion is exceeded, the bricks become brittle, soft, and fusible, at a moderately high temperature. The presence of lime in such quantities as to effervesce with acids, increases their softness, and causes disintegration in the bricks. The red colour of ordinary bricks is due to an oxide of iron; within certain limits this improves their quality, but more than 10 or 15 per cent of the metal gives an almost black colour, objectionable in architectural works.

According to Dr. Ure, the following is an analysis of clay that will make good red bricks:—

Silica	50·40
Alumina and Oxide of Iron	24·00
Carbonate of Lime	2·70
Carbonate of Magnesia	1·30
Water, &c.	21·60
	100·00

Professor Black has kindly analysed two samples of brick clay for me. No. 1 was taken from a heap in a brick-yard at Caversham, and No. 2 from a cutting at Lovell's Flat. They contain :—

		No. 1. Red Clay.		No. 2. White Clay.
Water (hygroscopic)	...	8·70	...	2·17
Water (combined) ...	...	2·60	...	7·76
Silica	...	61·90	...	55·97
Alumina	...	21·63	...	27·46
Oxide of Iron ...	...	6·37	...	3·24
Lime	...	0·30	...	0·34
Magnesia ...	...	0.32	...	0·39
Alkalies... ...	...	2·60	...	3·61
		104·42	...	100·94

This is such a close approximation to the English product in its essential constituents, that we may safely conclude there would be no difficulty in finding any quantity of clay in Otago identical in every respect with the English type.

The clays of this Province are so varied in colour and consistency, that, independently of their industrial importance, they form an interesting study. Some years ago I made a collection of about forty distinct varieties from the volcanic deposits around Dunedin. Many of them were of the most beautiful colours—bright red, yellow, and blue being quite common. When separated from the sombre tints of the surrounding earth, they resembled artificial dyes or paints more than natural products in a crude state. The pottery, fire, and pipe clays also demand special notice. They, too, exist in an endless variety throughout the Province. Although their colours are seldom very bright, they are ex-

tremely fine in texture, and unctuous to the touch, like fancy soap.

Manufacture.—Like everything else in this mechanical age, the manufacture of bricks is now done wholesale. Machinery is applied in almost every stage of the process, and in many cases there is only a few minutes from the time the clay is dug till the bricks are in the kiln. I question if this is an advantage so far as quality is concerned. The old-fashioned way of digging the clay in autumn, leaving it exposed to the action of the weather throughout the winter, and working it up in spring, is more conducive to the production of a good article.

Tempering, the next step in the manufacture, is also done in an imperfect manner. There is often no attempt made to reduce the clay to a perfectly homogeneous mass, consequently the bricks are full of cavities and other flaws, which make them twist and crack in the kiln, and impair their cohesive strength. With reference to the burning, a few years since it was scarcely possible to get a well-burned brick in Otago, but latterly a considerable improvement has been made in this respect. If the preparation and tempering of the materials were only brought to the same standard, there would be little cause for complaint.

The Hoffman, or German perpetual kiln, of which there are samples at Hillside, burns bricks, lime, or cement in a very effectual manner, at a fabulously small outlay for fuel. The principle is simply the utilisation of all the heat produced, which is done in a most ingenious manner. The air that

feeds the fire passes through the cooling bricks, in doing which it cools them, and in exchange becomes heated so as to act like a hot blast on the burning mass. Then the heated gases from the furnace are carried through successive stacks of unburnt bricks, by which means they are dried and rendered fit for the fire. The fuel used is dross or dust from the Green Island lignite, and it is put into the furnace in homœopathic doses with a trowel.

An ordinary English brick, when perfectly dry, absorbs 7 per cent. of its weight of water in fifteen minutes. I have made experiments to determine the absorbent property of the Colonial article, and find that a hard red brick absorbs 14 per cent., and a soft one 13½ per cent. of its weight in the same time. The fact of the soft brick having absorbed nearly as much as the hard one is a clear proof that the inferiority of the Colonial product is attributable more to the imperfect manner in which the raw materials have been prepared than to the deficient burning in the kiln.

Pottery and Tile Works.—The establishment of Pottery and Tile Works at Tokomairiro, Dunedin, and Wallacetown, and the superiority of the articles produced by them, prove conclusively the existence and practical utility of fire and pottery clays throughout the Province. The articles manufactured at those places require raw materials of the most varied kind, from refractory fire-clays, that resist the fiercest heat, to the mixed varieties, that melt in ordinary temperatures. Nearly all these clays are found in the railway cuttings between Tokomairiro and Clutha, and in the vicinity of

Wallacetown. The establishment of the Tokomairiro and Dunedin works may be traced directly to the construction of the railway, which revealed the existence of the raw materials in the locality named.

Although the bulk of the articles manufactured at an ordinary pottery have no connection with the building arts, there are many of its products that can be utilised. In addition to the common drain-pipes, chimney-pots, and tiles, we shall soon want tesselated pavements for halls and hearths, and terra cotta goods of all kinds for ornamental purposes.

The raw materials for these articles exist in considerable quantities throughout the Province; so I have no doubt a supply of native manufacture will be forthcoming as soon as the demand arises.

CHAPTER VI.

Concrete.

General.

AT this stage concrete will be considered as a substitute for stone and bricks only. The properties of the native ingredients will be more fully discussed in a subsequent chapter on "Limes, Cements, and their Aggregates."

Perhaps there is no building material in existence to which so much attention has of late years been directed as concrete; and with reference to its principal ingredient—Portland cement,—the feeling in its favour is almost a mania; it is applied to

every conceivable purpose, from the huge monolithic mass that resists the greatest force of the ocean in a breakwater, to the plaster on the bottom of an ironclad, that prevents the adhesion of marine plants and animals. In such a multiplicity of uses it is impossible to avoid occasional failure; but this has resulted more from an erroneous estimate of the properties of the material and its consequent misapplication, than from incapacity to perform its proper functions. Another cause of failure, particularly in house-building, is the want of skill and care in mixing and depositing the ingredients.

The use of concrete as a building material is not confined, as is sometimes supposed, to the present age; it enters into the composition of many of the pyramids of Egypt, the Roman temples, and the feudal castles of Great Britain, whose substantial appearance still attract attention. It should, however, be explained that the often quoted superiority of those ancient structures is a popular fallacy. When tested in a scientific manner, it is clearly proved that their reputed strength will not bear comparison with modern masonry. In fact, there has been no mortar, ancient or modern, whose cohesive properties approach in the most remote degree those of Portland cement.

Although used to a considerable extent by the ancients and in mediæval ages, concrete has not for several generations been applied to the ordinary purposes of the house-builder. The invention of artificial cements has of late years given a fresh impetus to the art, and it has already in many cases fairly supplanted stone and brick.

Properties.—The advantages claimed for concrete, and the uses to which it is applied, are too numerous to be discussed here. I shall, however, take a cursory glance at some of its more prominent features. The first, and in my opinion highest, property to which it lays claim is the facility afforded for building massive structures without the expense of lifting or transporting heavy weights; its superiority over all other materials in this respect is undoubted, consequently it will always take the foremost place in breakwaters, foundations, and other works of a massive character.

Durability is a property to which concrete lays special claim, and I think with good reason, for it increases in strength with age, while most other materials commence to deteriorate from the moment they are put into the building, Lime, which is of a perishable nature, enters into the composition of cement concrete; but as the portion is so small, seldom exceeding 10 per cent., and as the lime is protected by the silicates and other ingredients that are in combination with it, the deleterious acids of the ocean or atmosphere can have little effect on the mass.

The advantages of cheapness, strength, dryness, and many other good qualities to which concrete lays special claim, are not like those already mentioned, "constant quantities." They depend so much on locality, cost of ingredients, and skill in construction, that no general comparison can be established between it and other materials for which it is a substitute.

The chief drawback to the use of concrete is the

difficulty of ensuring good materials and workmanship and the risk thereby incurred. From the peculiar nature of the work and the ingredients employed, the margin of safety is very small. There is only one step from absolute security to utter failure, and that step may consist of a simple act of carelessness in selecting the materials. It is popularly supposed that any ordinary labourer can build a concrete wall, but such is not the case, the amount of skill and attention required, particularly in house-building, is equal if not greater than that demanded from the tradesman.

Uses.—In addition to marine works, for which it is pre-eminently suited, concrete has within the last few years been applied to an infinitude of purposes ashore. In England it has been used for pavements, causewaying, and water-pipes, as well as bridge-building and ordinary architectural and ornamental works. Paris has 32 miles of sewers, and 37 miles of an aqueduct in concrete. The latter is the most extensive work of its kind in existence; there are nearly three miles of arches, some of them being 50ft. in height and 40ft. span. The village of Vesinet, near Paris, has a Gothic church entirely of concrete in one piece from foundation to spire; and the lighthouse at Port Said, 80ft. high, is of the same character.

Concrete is either built in blocks previously moulded and laid like stones or bricks, or in what is called the "monolithic system," which consists in laying the soft ingredient between frames in the position they are ultimately intended to occupy. The former is undoubtedly the better, as it does

away with the risk of using faulty materials; but the latter is much cheaper, and on that account is more generally adopted. The simplest form of block is that of common bricks; in England these are manufactured in large quantities by machinery, and form excellent building materials. A compressed concrete brick composed of one part of cement to six parts of sand, will, when six days old, resist a pressure of 18 tons, which is about double the strength of ordinary red bricks. Concrete is cast into blocks for arch-stones, quoins, sills, lintels, steps, and mouldings of all kinds.

Making Concrete.—At the risk of introducing technicalities, I shall, in view of the interest taken in the subject, devote a few remarks to the consideration of the mode of making concrete. The cementing ingredient in concrete is generally hydraulic lime or cement, or a mixture of the two. The former has not yet been used as such in Otago, neither has the latter been manufactured, so they cannot be called native; but as the raw materials for making cement exist in large quantities, there is no doubt its manufacture will become a Colonial industry at no distant day.

The proportion of cement to the aggregates varies from a fourth to a sixth, according to the nature of the work, the strength of the cement, and the character of the other materials; for house-building one to six is weak enough, particularly here, where the cement may have deteriorated by exposure on the voyage.

The best aggregate is one in which the pieces are of all sizes, from 2in. metal to fine sand, adjusted

in such regular gradations that the cement will exactly fill the vacuities. Large metal and fine sand, without other materials of an intermediate size, do not make good concrete.

The ingredients should be mixed dry, and water added in infinitesimal quantities, through a fine rose or otherwise, in the form of spray. This is an important point, for a wash of water enriches one portion of the mass at the expense of another. No more water should be put in than sufficient to damp the cement, as a certain limited quantity only is required. In setting, the excess evaporates, and leaves cavities for the reception and retention of moisture.

Mixing, the next operation, is also equally important: it must be done in a thorough systematic manner, so that every piece of stone or particle of sand is completely coated with cement. It is almost impossible to get this work done properly by manual labour, and although machinery is constantly employed on large works, the necessity for it in ordinary house-building is not yet fully recognised.

The manner of depositing the materials in the moulds or frames has given rise to a difference of opinion: some writers hold that the concrete should be placed loosely, because pressure impairs the setting properties of cement; but the leading authorities advocate excessive ramming. If Roman or any other quick-setting cement is used, pressure will undoubtedly do harm; but with ordinary heavy Portland cement, or hydraulic limes, in the proportions usually adopted, there is no risk in ramming,

and the quality of the concrete is so much improved by it, that if necessary it would be better to retard the setting of cement by a mixture of ordinary lime, or by prolonged mixing, than omit the operation.

The large French works that I have mentioned are all built of a concrete invented by Mons. F. Coignet, and known as "béton agglomere," the composition being as follows :—

Hydraulic lime	1	or	1
Portland cement	$\frac{1}{5}$		$\frac{1}{4}$
Sand or gravel not larger than a pea ...	5		4

This has been the most successful application of concrete to ordinary building purposes hitherto recorded, and the result is due almost entirely to careful manipulation. In addition to the essentials of a proper adjustment of the ingredients and thorough mixing with the minimum quantity of water, great stress is laid on the necessity for heavy ramming. The concrete is laid in thin layers, and hammered with iron-faced beaters till each layer is compressed to a third of its original thickness. The surface is then raked to form a bond with the next layer, and so the work is carried on continuously to the end. The result of this careful treatment is, that "béton agglomere" is one of the most compact, impervious, and durable building materials at present in ordinary use.

General Gillmore, of the United States army, in reporting to his Government on this question, made some experiments to determne the relative strength of concrete prepared in the

usual way, and in the method adopted by Mons. Coignet, I give a few results :—

Compresive strength, Crushing weight of Portland Cement, pure and mixed with sand, in pounds per square inch, on blocks seven days old:

	Rammed.	Loose.
Pure Cement ...	2846¾ (not crushed) ...	2597
1 of cement to 1·7 of sand	2804½	1038
1 to 3·4	930	727
1 to 5	519	259½
1 to 6·8	259½	104¾

Tensile strength under same conditions:

1 to 1·7	138	109
1 to 5	66	33
1 to 6·8	39	24

Independently of these experiments, the defect of the loose method of depositing concrete in buildings is apparent to any observer. The cavities occasionally amount to a third of the whole, consequently a nine-inch wall is no stronger than one of six inches in which the materials are compressed into a solid mass, and the porosity of the structure must be proportionately great. If it is possible to ram "béton agglomere" into a third of its original bulk, it is quite obvious that the voids in the unpressed article must equal or exceed the solid parts, or that the whole mass lacks the density essential to strength and impermeability. A coat of plaster on the outside of a building will not, as is sometimes supposed, effectually keep out damp. At the most, Portland cement and its mixtures are only limestone or calcareous sandstones or grits, and as such, are more or less absorbent. It is therefore

necessary to convert them into the compact state by pressure, if we want to resist moisture, and it is impossible to do so in plastering.

Experiments.—Although some thousands of experiments have within the last few years been made to determine the strength of Portland cement and its mixtures under every conceivable circumstance, there is no record of any regular experiments having been made to test its powers of resisting damp. General Gillmore made one or two trials of "béton agglomere," and he pronounces it to be practically impervious—the amount of moisture absorbed in four days was immeasurably small. An Indian engineer, Mr. Horace Bell, found that neat Portland cement absorbed 20 per cent. of its weight in an hour, and 25 per cent. in three hours.

In view of the paucity of our information on this subject, I made a few experiments with samples in my possession. The specimens were not prepared for this purpose, so the proportions of the various ingredients and mode of mixing them were not recorded with the exactness necessary in a thorough investigation; the results are, therefore, not advanced as absolutely conclusive.

	Weight of water absorbed after $2\frac{1}{2}$ hours' immersion.
Neat Portland cement—Lump taken from a damaged cask, the original powder having been consolidated by hydraulic pressure ...	2 per cent.
Neat cement, from the Rangitata Bridge, four years old. It had been pressed into a mould with a trowel, like ordinary mortar	$6\frac{1}{2}$ per cent.
Neat cement. Another sample like the last ...	8 per cent.

Cement mortar, from Abbotsford Bridge, two years old—1 of cement to 3 of coarse sand	9 per cent.
Concrete, one year old. Made from 1 of cement to 7 of tailings—the sizes of the ingredients being well adjusted, and the concrete very compact	$4\frac{1}{2}$ per cent.

Another experiment was made with a specimen block of concrete made by the proprietors of the Logan Point Quarry. It was composed of 1 of cement to 7 of fine road metal and small stuff from the stone-breaker. None of the metal was larger than an inch each way, and the other ingredients were well adjusted. The concrete was not heavily rammed, like "béton agglomere," but it seems to have been very firmly pressed. Altogether, it was a first-class piece of concrete, and the greatest difficulty was experienced in breaking it up with a wedge and heavy hammer. The block measured 24 inches long, 12·25 inches high, and 10·08 inches broad; and weighed, when dry, 240lbs., the outside being covered with a thick coat of rich cement plaster, as it is intended to have in a building.

The first experiment was to determine the impermeability of the plaster. A wall of clay was put round the edge, leaving a square foot exposed. Water was poured on, and in three hours about three quarters of a pint had penetrated the surface. The whole block being then immersed, it instantly absorbed $2\frac{1}{2}$lbs. more, and in 16 hours the quantity had further increased to 4lbs. On breaking, it was found that the moisture had permeated every portion of the block, and the centre was as wet as the outside. The two samples of concrete thus

experimented upon were of a very superior quality. I have never seen anything to compare with them in ordinary work.

Although these experiments are very crude, and the results much higher than would be obtained from less carefully prepared specimens, they go a long way to prove that the property of perfect immunity from damp to which concrete houses lay claim, is not secured by the mode of building usually adopted in Otago, and I believe the experience already acquired in actual practice fully supports this assertion.

CHAPTER VII.

Comparison of Various Building Materials.

Strength.

I SHALL first consider the strength of the various materials under discussion so as to compare their cost. The properties of brickwork being so well known, it has from time immemorial been selected by municipal authorities as the standard from which to determine the strength of buildings, and there are regulations in every town fixing the thickness of brick walls in whatever position they occupy. I shall therefore adhere to the same standard.

The following table gives the crushing strength of various kinds of building materials in common use :—

	Crushing weight per square inch in pounds.
Brick, weak red	550 to 800
Brick, strong red	1,100
Brick, first quality	2,000 to 4,370
Ordinary brickwork	390
Good brickwork in cement ...	550
Best brickwork in cement ...	930
Neat Portland cement 9 months old	5,970
1 of cement to 3 of sand ...	2,400
1 of cement to 5 of sand ...	1,100
Béton agglomere 15 months old, with hydraulic lime of Argentine ...	2,650
Same, 18 to 31 months old ...	3,300 to 5,360
Béton agglomere, 21 to 30 months old, with hydraulic lime of Thiel ...	5,650 to 7,180
Béton agglomere, 2 months old, made from 1 of hydraulic lime, and 1½ cement to 5 of sand	1,690
Same, with one part of cement only	1,860
Same, with ½ part of cement only ...	1,450
Chalk	330
Ordinary sandstones	3,300 to 4,400
Compact sandstones	9,800
Limestones generally	3,100 to 8,500
Caen stone	1,100
Basalts and granites	9,500 to 13,000

Smooth-dressed ashlar in large blocks, with cement mortar, is practically as strong as the stone of which it is built, but rubble masonry is three-fifths weaker. We may therefore assume the crushing strength of this class of work, built from our native bluestones and hard breccias, at 4,000 pounds per square inch.

From the above data, the relative thickness of walls of equal strength in the ordinary building materials would be approximately as follows:—

Good Brickwork	1·00
Ordinary concrete	0·33
Bluestone rubble	0·15
Béton agglomere	0·10

Although in theory correct, it is practically impossible to adopt this standard, for we all know that 9-inch brick walls are sufficient for a one-storey house; but the idea of reducing them to one inch is altogether too absurd to be entertained, no matter how strong the material may be. The objection also holds good with the thickest walls, for weight and breadth of bearing are as much required as cohesive strength. Those who maintain that concrete is superior to any other building material advocate thin walls, or at least affirm that they are permissible; and many houses have been erected, the sides of which resemble monumental slabs more than the habitation of the living man. I find, however, that Mons. Coignet, who has had more experience than anyone else, does not build excessively thin walls; those of a house of six floors and a cellar erected by him in Paris commence with a thickness of 19·8in., and terminate at the topmost storey with 9·8in., the average being 13½in., which is within three-quarters of an inch of the thickness required by the Metropolitan Buildings Act for the walls of the same house in brick or stone. Concrete buildings in London are generally built to the same standard as brick. The walls of an extensive carriage and engine shed lately erected for the Metropolitan District Railway Company, although only one storey in height, are 18 inches thick, with piers at short intervals.

From all this it may be inferred that full advantage cannot be taken of the extra strength obtained by substituting concrete for brickwork. We must therefore rest satisfied in having raised the standard by getting a stronger and more durable article. Still I think some little allowance might be made in the thickness of walls. Perhaps the following would be a fair proportion to adopt in building with the materials at present commonly used in Otago :—

	Inches.
Concrete and Bèton	12
Ashlar masonry	12
Brickwork	$13\frac{1}{2}$
Rubble masonry	18

The increased thickness of walls in rubble masonry is not determined by deficient strength, but by the difficulty in building thin walls with rough stone.

Cost.

Having discussed the properties of stone, bricks, and concrete, the materials of which the walls of our buildings are composed, I shall consider shortly their relative cost. Of course, timber is still in general use for walls, as well as its more legitimate functions of roofing and internal fittings; but having properties and uses peculiar to itself, it will be treated at length in another chapter. I shall, however, at this stage compare the cost of timber in the walls of buildings with those of the other materials mentioned.

It is impossible to determine a general rule on

the subject of cost and suitability, as they depend so much on the resources of the locality and the purpose in view, not to mention the wider range of individual tastes. The following conclusions are applicable to Dunedin, but they will give at least indications of results in other parts of the Province by making the allowance due to a difference in the value of materials and labour.

It is authoritatively stated that the cost of concrete in London is only one-half that of brickwork for the same thickness of wall, and the béton agglomere sewers in Paris are calculated to have cost 20 per cent. less than any other material procurable of the same quality. It must, however, be borne in mind that in both these places the circumstances are very much in favour of this result. The cementing ingredients are manufactured on the spot, consequently concrete is on a par with brickwork, and has an advantage over stone which comes from a distance. In Otago the conditions are exactly reversed. Brick and stone being in the locality, can be procured at a moderate rate, while cement has to bear the heavy charges inseparable from the importation of a low-priced article. When the manufacture of Portland cement is established in New Zealand, the relative costs of the three building materials will in all probability approach nearer the European proportion. The price of concrete in plain walls, near London, with cement at 8s. per cask, is from 9s. to 11s. 6d. per cubic yard. Béton agglomere in Paris for the same work, with cement at 8s. per cask, hydraulic lime about one-half that price, and labour 3s. per day, costs from 20s. to 24s.

per cubic yard. The greater cost of the latter is a proof that there is more labour and care bestowed on its preparation than is done with concrete in England.

The price of concrete for ordinary engineering purposes in Dunedin is about 35s. per cubic yard; and Mr. Petre, who has had considerable practice in building with concrete, informs me that its price in a plain wall is about 41s. 6d.; if to this is added the cost of outside plastering, which is indispensable in any class of dwelling-house, we bring it up to 50s. I am not aware of any building having been erected in Otago in strict accordance with the method adopted in France, so there is no way of getting at the cost from actual experience; but the data at command are sufficient to fix 60s. as a close approximation. In America, the price of béton is estimated at from 36s. to 44s. for labour and materials alone, and those are much cheaper than with us.

The following statement gives the comparative cost of building in London and Dunedin at the present day:—

	London.		Dunedin.	
	s.	d.	s.	d.
Ordinary brickwork, per cubic yard ...	22	0	40	0
Concrete	11	0	50	0
Béton agglomere	22	0	60	0
Rough rubble	12	0	27	6
Coursed rubble	18	0	37	6
Freestone ashlar, per cubic foot ...	3	8	4	6
Hardstone ashlar, rock-faced, per cubic foot	10	0	4	6
Hardstone ashlar, fine-dressed, per cubic foot	11	0	6	6

At those prices, and the standard thicknesses of wall formerly established, the relative cost of building in Dunedin, with the various materials at command, is as follows :—

Brickwork	1.00
Concrete	1.11
Béton agglomere	1.33
Rough rubble	0.91
Coursed rubble	1.25
Freestone ashlar	2.70
Hardstone ashlar, rock-faced	2.70
Hardstone ashlar, fine-dressed ...	3.90
Ordinary timber-work in walls ...	0.44

This proportion is not, however, applicable to the whole building, for the value of the masonry is generally less than half the total cost. Furthermore, the high-priced materials are seldom used in large quantities. The front of a business place in a street, or the facings in an isolated dwelling-house are all that is required to be of this class.

Mr. Lawson estimates the difference in cost of brick over timber in an ordinary dwelling-house at from 33 to 50 per cent. Taking it at a mean of those rates, a wooden house worth £1,000 would cost £1,400 in brick, the cost of the walls being respectively £300 and £700. The interest of the amount saved is sufficient to rebuild the walls every ten years, which is oftener than required, but it is not sufficient to renew the whole house when the walls decay—a very probable contingency—for the renewal of the walls entails, practically, the entire reconstruction of the building. Besides, the interior of a wooden house is more subject to deterioration and injury than that of a brick or stone

one; and the permanent charges, such as repairs, painting, and insurance, are always much higher.

Independently of the increased comfort and security obtained, I believe that even now it is true economy to build our houses with the more durable materials; and when the railways are in full working order, north and south, the matter will be placed beyond doubt.

At present Oamaru stone costs 5d. per cubic foot, in blocks at the quarries, and 3s. 6d. in the same state in Dunedin. When the railway is opened it should be brought into Dunedin at 1s. 6d., the price when laid being 2s. 6d., which is a saving of 44 per cent on current rates. The brown and grey freestones of Waihola are already within reach of railway carriage, and will be conveyed to town for about 4d. per cubic foot, so that they can be sold for 1s. 6d. As already stated, the former is too hard for fine work, but the latter is an admirable substitute for the Oamaru stone; it is a compact limestone of the proper consistency—soft enough to be easily worked, but sufficiently hard to stand the weather.

I trust, therefore, that one of the first benefits our city will derive from the establishment of railway communication is the improvement of its architecture.

CHAPTER VIII.

Roofing Slates.

Locality.

WHEN I began to collect data for these papers I did not expect that anything would be said on this head further than to report that no good roofing materials had yet been discovered in Otago. I am glad to state that this blank in our resources has within the last few months been filled up by the discovery of a valuable deposit of slate in the Otepopo district. The existence of a seam in this locality has been the subject of rumour for some years, but it remained for Mr. Short, of the Land Office, to place the matter beyond doubt. He first discovered slate at Mount Domett, but knowing that it was too remote to be worked to advantage, he traced the reef back towards the sea, and eventually found workable deposits on the Kauroo stream and its tributaries, at which point the reef approaches nearest the coast and the settled districts.

As stated in a former paper, roofing slate should be found in the Kakanui or Silurian formation, which, according to Professor Hutton, exists in this Province in two large zones, extending from east to west across the country; that in the north begins at Otepopo and terminates at the Hawea

Lake. It embraces the Kakanui and Hawkdun Mountain Ranges. The southern belt commences at Tapanui, and sweeps round by Athol and the head of Lake Wakatipu to the Forbes Mountains. A connection between these zones, along the western seaboard, can be traced in isolated patches at Waitahuna, Akatore, Otakia, and the Silver Peaks.

Although this extensive tract of country is entirely slate, in the geological sense of the word, it does not follow that the supply of roofing material is proportionately great, for the conditions that seem necessary for the production of the slate of commerce do not occur frequently in the clay-slate formations of any conntry.

As already stated, Mr. Short discovered what he takes to be a good roofing slate at Mount Domett, in a position tolerably accessible from the Marewhenua country, and the same quality is known to exist at the Lindis Pass. Both these places are too remote to be available at present, but it is satisfactory to know that the store of wealth is there, although it may not be realised for many years.

The exact locality of the Otepopo slate reef is about half a mile west from Charles Peak, at the confluence of a small tributary of the Kauroo with the main stream, the distance from the township of Herbert, in a direct line, being about eight miles.

The West Coast has been well prospected for slate by Mr. McInnes, a practical quarrier, but he discovered nothing better than the hard, coarse variety discovered at Preservation Inlet, specimens of which are in the Museum. This result is to be

expected, for the rocks on that side of the island are too old and crystalline to produce a good article.

Extent.—The slate deposits on the Kauroo are of a vast extent. Professor Hutton, in a recent report on the subject, says :—

"The thickness of the bed forming the present face cannot be as yet ascertained, but is no doubt considerable. The side of the valley, above the quarry, rises very abruptly, so that before long the height of the workings will be over 100 feet, and will continue to rise to 500 feet, so that a comparatively thin bed even would produce an enormous quantity of slates. In addition to this bed, there are at least two others higher up the valley, both of which will be available for working when the fallen rubbish is cleared from the surface. Higher up the hill other outcrops of good slates are seen, so that no doubt the supply is practically inexhaustible."

Mr. Macpherson, a practical slate quarry surveyor, from Wales, bears similar testimony to the extent of the deposits, and states further that the quality of the slates and the facility for working the quarries, are superior to anything he has seen in the Old Country. In England, slates are usually obtained from comparatively thin layers surrounded and embedded in hard rock. The best vein at Bangor is only 60 feet thick. At Otepopo there seems to be a whole mountain of the material, perfectly homogenous, and nearly all available.

Quality.—The value of our slate deposits is very much enhanced by the fact that the product is infinitely superior to anything hitherto discovered in the other Australian colonies. I have compared the Otago slates with samples from various parts of England, America, Australia, and Tasmania, and

so far as I can judge, the Blue Welsh is the only rival it has. Indeed, the resemblance between them is so great, that when similarly grained specimens of the two kinds are placed together, the best judge can scarcely distinguish them.

It will also be seen from the following comparative analysis of American, Welsh, and Otago slates, that the little difference in chemical composition between the Welsh and Otago samples is in favour of the latter, inasmuch as it has a slight preponderance of the imperishable ingredients :—

	Welsh.	American.	Otago.
Silica	60.50	56.65	65.44
Alumina	19.70	19.33	21.04
Protoxide of Iron	7.83	7.12	6.20
Lime	1.12	2.77	0.75
Magnesia	2.20	1.00	0.44
Alkalies	5.38	8.30	4.49
Water	3.30	5.15	3.75
	100.03	100.32	102.11

The analysis of the Welsh slate is given on the authority of Professor Hull, of Dublin, and the other two were made by Mr. P. S. Hay, M.A., of the Otago University.

The following analysis of Welsh slate from Bondroff, is given by Dr. Bischoff, who found that there was no practical difference in the composition of thirty-six analyses made by him. It will be observed that this sample approaches still closer to

the Otago slate in its essential constituents than the one by Professor Hull :—

Silica	62.59
Alumina	16.88
Protoxide of Iron	8.42
Lime	0.24
Magnesia	2.26
Potash	3.31
Oxide of Copper	0.13
Carbonate of Lime	1.22
Water	4.03
Carbon and Loss	0.92
	100.00

Referring to the quality of Otepopo slate, Professor Hutton says :—

"On my first visit to the district, when slates had only been found in the upper part of the valley, I doubted their being equal to Welsh slates, although I then reported to the Government that 'they would be found nearly equal to them for roofing.' But the bed now opened up lower down the valley is of a very superior quality, and quite equal, I think, to the Scotch and Welsh slates. The slates split easily, and with a perfectly flat cleavage. They are of a dark blue colour, and have a fine silky lustre. They can be made quite as thin as desirable. They cut well without splintering, and stand a hole being knocked through them with a hammer or chisel. Their hardness is quite sufficient, and that they will stand the weather perfectly is proved by the excellent state of preservation of surfaces long exposed to the weather. I have seen large blocks looking as sharp and fresh as if they had just been detached from the rock, which were almost buried in the vegetation that had grown up around them; while the very small amount of vegetation (confined to lichens)

growing on the exposed surfaces showed that they do not readily absorb moisture."

These observations and conclusions agree entirely with my own. Roofing slates are found of all colours from a creamy white to black, but experience proves that the bluish-grey coloured varieties like the Otago ones are decidedly the best. In addition to being an indication of liability to decay, nearly all the other colours fade on exposure. The other essentials of good roofing slate are—compactness of texture, impermeability, and the facility with which they can be split parallel and without twist. The Otepopo slate possesses all these properties in a pre-eminent degree. I placed a Welsh and an Otago slate side by side in water for 48 hours, and found that while the moisture rose from three-eighths to half an inch in the imported article, it did not rise at all in the colonial; which proves that the latter is the more compact and impervious of the two.

The facility of splitting is also fully established, for the many samples to hand are of all thicknesses and perfectly true to shape, and I have seen the slates split well with a common pick instead of the broad chisels used by the quarriers. As a matter of experiment the splitters frequently take sixteen slates from one inch of stone. The following gives the relative weight of various sizes of Otago and Welsh slate. The weight of the Otago slates is calculated from the dray loads as they leave the quarries, consequently all qualities are included, but "first quality" only is included in the Welsh

weights. This makes a further difference of lightness in favour of the native article.

Comparative weight of Slates, per thousand :—

Sizes.						Otago. Average of allqualities	Welsh. First quality.
						Cwts.	Cwts.
20 inches by 10 inches				...	...	26	$33\frac{1}{3}$
18	"	"	9 "	...	...	22	25
16	"	"	8 "	...	...	$17\frac{1}{2}$	21
14	"	"	8 "	...	...	$14\frac{1}{2}$	$18\frac{1}{3}$
12	"		6 "	...	...	10	$10\frac{1}{2}$

Professor Hutton, in his "Geology of Otago," informs us that there is a considerable difference between the cleavage of the Otago and English slate; instead of being at an angle to the strata, it is parallel to them. He alludes to this as a possible defect in the colonial article, but at the same time states that the property of splitting readily is not due to lamination, but cleavage; consequently the pressure that gave this property must have been applied in a vertical rather than a horizontal direction. Without venturing to express an opinion on such an important geological question, it seems to me that the idea of a regular vertical pressure, induced or aided by attraction of gravity, is more natural than a horizontal one; not only is the pressure in the former case abnormal, but we must pre-suppose the existence of a solid mould which prevented the lateral extension of the material. It is popularly believed that the roofing slates of England are nearly all extracted from beds with inclined cleavage, and those taken from a horizontal

stratum, where the angle of the cleavage planes is greatest, are supposed to be the readiest split, and otherwise the best; but recent authorities show that, although general, this is not invariably the case. Cleavage occurs at almost all angles, and in some of the best slate veins it is nearly parallel with the bedding. Messrs. Langley and Bellamy, in a paper contributed to the Institution of Civil Engineers, give a section of the Festiniog District, in which the angle between the planes of stratification and cleavage is only 15 degrees; and Mr. D. C. Davies, in his new book on "Slates, and Slate Quarrying," referring to a quarry in Carnarvonshire, states that owing to the curvings of the lines of bedding, "the lines of cleavage sometimes nearly coincide with them." The existence of a cleavage of this kind in the clay-slate formation is well known. Darwin noticed it in the Andes; and Geikie says:—"Cleavage may either coincide with the original lamination of the rock, or cut across it at all angles." It is, therefore, possible that the exception in the Old Country is the rule at the antipodes. Under any circumstances the question cannot affect the industrial importance of the Otago slate. While we are satisfied that it splits freely, and is durable and impervious, its geological peculiarities may be disregarded.

Products.—The Otepopo Slate Quarries have been taken up by a Dunedin company, and are now worked in a systematic manner. Nearly half a million slates of various kinds have already been obtained. The great drawback to the rapid deve-

lopment of the industry is the inaccessible situation of the quarries. Although only twelve or fourteen miles from the railway, the intervening country is rather rough, so it will be necessary to construct a road or tramway to bring the slates to the market.

In addition to roofing material, slate quarries yield slabs for paving, hearths, mantel-pieces, and other works of a similar kind; the finer sorts are usually too smooth and soft for street pavements, but I have no doubt varieties suitable for this purpose will be found in the same locality.

Cost.—Following the plan adopted with the other materials, I shall devote a few remarks to the consideration of the comparative cost of slate and its principal substitute—corrugated iron.

It is popularly supposed that there is a great difference in the cost, but such is not the case. Having occasion lately to decide on a covering for my own house, I calculated the difference carefully, and found that, with Countess slates at £15 per thousand, and galvanized iron at £37 per ton—which were then the current retail prices—the cost of the two materials was identical for the same space of roof. There is, however, a difference in favour of the iron in cartage, timber-work, and labour, amounting to 10s. per square, or 16 per cent. on materials and labour combined. This is a large proportion, as such, but when we consider that it only amounts to about £10 on a house 40 feet square, the wonder is that any iron is used. Whether regarded as a matter of appearance, freedom from sound and extremes of temperature, or durability, the superiority of slate over iron is un-

doubted; and were the difference in cost twice as great, the balance of advantages would still be on the same side.

General.—According to the Customs Returns, the value of roofing materials imported into New Zealand during 1876 was £115,734; if to this be added charges of importation and the importers' profits and the value of native shingles, it makes a total of £160,000 or £170,000. Assuming that £40,000 worth of iron is used for the walls of houses, fencing, and similar purposes, we have a balance of £120,000 or £130,000 as sent out of the colony for roofing materials which, in all probability, we have at our doors. In addition to this home consumption the absence of good roofing slate in Australia makes the development of an export trade a mere matter of time.

I question the wisdom of fostering or encouraging, at this early stage of our history, every industry that may ultimately be required or that may succeed in the colony at some future time; but in the case of a low-priced article like slates, the value of which is doubled by freight, and the other charges of importation, there is little wanted to turn the scale in favour of the native production. I believe the enterprise that establishes and carries on the industry, and the individual support it receives, are sufficient to do so. We may therefore hope to see the imported roofing material fairly supplanted by the native article at no distant day, and that ultimately the export trade will become so extensive as to influence the finance of the colony generally.

SECTION II.

LIMES, CEMENTS, AND THEIR AGGREGATES.

CHAPTER I.

Description of Cementing Materials.

Definition of Terms.

BEFORE proceeding to treat in detail the native productions, it is necessary to consider the properties of limes and cements generally. In doing so, I should begin by stating that the terms "Lime," and "Cement," although always used to denote different and distinct articles, are applicable to either of them. The cementing ingredients are the same in both cases, the only difference being in the proportions in which they occur. Pure lime is practically worthless for building purposes; it never acquires the necessary cohesive strength in any situation, and never hardens at all in a damp place. In order to make good mortar, the limestone must contain a mixture of clay; the proportion varies from 8 per

cent. in ordinary building lime to 35 per cent. in strong hydraulic cement. If it were necessary to have a clear dividing line between limes and cements, the best place to strike it would be at the neutral point where the adhesive and cohesive forces are equal. The particles of rich and moderately hydraulic limes adhere more readily to a foreign substance than to each other, but the conditions are reversed with strong hydraulic limes and cements. This gives the only tangible difference I can imagine between the two articles, but as it does not admit of a practical application, the distinction would only be valuable from a scientific point of view.

Classification.—Limes and cements are usually divided into four classes, according to their properties and strength:—

1st. *The Common or Rich Limes* that contain less than 10 per cent. of clay other or impurities.

2nd. *Poor Limes,* in which the impurities consist of from 10 to 25 per cent. of sand and other insoluble ingredients that will not enter into chemical combination with the lime.

3rd. *Hydraulic Limes,* such as contain from 10 to 30 per cent. of alumina and soluble silica.

4th. *Hydraulic Cements,* containing from 30 to 40 per cent of alumina, soluble silica, and other impurities.

Composition.—In addition to the ingredients named each of the above classes frequently contains small quantities of iron, maganese, magnesia, potash or soda, with sulphuric and other acids, which do not seem to have an injurious effect on the cementitious

properties of the article; on the contrary, some of them, such as iron, and soda, and some of the acids, are always present in the best cements; the quantity, however, of all foreign substances, except silica and alumina, seldom exceeds 5 per cent. We may therefore assume, shortly, that our mortars are simply lime and clay in varying proportions.

As already stated, the common or rich limes are comparatively useless where strength is required, and absolutely worthless in a damp situation. They are easily burned and slaked, swell to a great extent in slaking, shrink in drying, and are soluble in water when set. Their adhesive properties are stronger than their cohesive ones, consequently they cannot be used without a large admixture of sand. It is common to hear the expression that mortar is injured by too much sand, but the chances are that its bad qualities are the result of the opposite condition, and, above all, that the sand and lime are not properly mixed. If greater care was exercised in this behoof, so that an approach could be made to the theoretical maximum of an atom of sand alternating with an atom of lime, the result would be an immediate doubling of the strength of rich lime mortar.

Poor Limes possess all the bad qualities of the rich ones, and have an additional drawback in irregularity of consistency through not slaking so readily, which necessitates grinding.

Hydraulic Limes are frequently subdivided into three or four sections, ranging from "slightly" to "eminently" hydraulic, the former being practically

a rich lime, and the latter a cement. These limes do not slake readily, nor do they expand much in the process. The higher kinds slake so slowly and so imperfectly that they are always pulverised by grinding. Hydraulic limes set under water in from three to fourteen days, according to the strength of the sample.

Hydraulic cements cannot be slaked by water in the usual way; they are, properly speaking, not calcined, but vitrified. The produce of the kilns resembles slag from a blast furnace, and it requires the aid of stone-breakers, iron rollers, and French burr millstones, to convert it into the cement of commerce. In common with the higher kinds of hydraulic lime, cement does not require any admixture of sand to make it into mortar; the maximum strength is obtained by using it in a pure state. Some hydraulic cements set under water in a few minutes, but the best kinds take a few hours. In seven days the latter attain a tensile strength of 250 pounds to the square inch.

Quality of Limestones.—The quality of limestones cannot be determined by a knowledge of the geological formation in which they occur, nor by their general appearance. Hydraulic limes are perhaps more plentiful in what may be called the mediæval rocks—cretaceous to carboniferous—than in any others; but as they are frequently met with in the formations above and below those named, we may give them an almost universal range of locality. The character of the stone seems to be determined chiefly by its immediate surroundings—the outer beds are argillaceous or silicious—

according as the adjoining stratum is clay or sand, and the whole rock is influenced by the manner in which it was deposited, and the subsequent changes to which it has been subjected. If the lime had been deposited in still, clean water, on a rocky bottom, and had attained a considerable degree of hardness before being disturbed by convulsions from below, or pressure from above, we might expect it to be comparatively pure; but if deposited in an estuary where the water is muddy and the bottom soft, and where floods leave occasional beds of silt and sand, the stone cannot fail to contain impurities. Even after the deposit has taken place the stone may be altered by mechanical and chemical agencies, there being a peculiar affinity between the lime and clay in hydraulic limestone that seems to be easily affected by external causes. A good illustration of the influence of its surroundings on the character of the stone is found at Mr. Macdonald's quarries, Otago Peninsula. The rock is much shattered, and divided into large blocks by "backs" running through it in all directions. The blocks in one of the beds produce two distinct varieties of stone, the analyses of which are given in Nos. 13 and 15, Table III. The light-coloured stone occupies from two to three feet of the outside of the block, and gradually merges into the dark one which composes the heart; they vary little in consistency, but, as will be seen from the table, there is a great difference in their composition. Assuming the block was originally homogeneous, of which there can be little doubt, we find that the crust has lost 4 per cent. of carbonate of lime, and $2\frac{1}{4}$ per cent. of car-

bonate of magnesia, while, on the other hand, it has gained 2 per cent. of iron, in addition to the increased percentage of silica and alumina due to the abstraction of the lime and magnesia.

Hydraulic limestones are generally compact in texture and dark in colour—grey, blue, drab, or brown, being the prevailing colours; white indicates pure lime. It does not, however, follow that all the dark-coloured limestones are hydraulic, for they may contain sand and other insoluble matters that neutralize the effect of the clay; and the darkest of all limestones—black marble—is almost pure carbonate of lime. Still, a rule may be established in a negative manner by saying that no white limestones produce hydraulic lime.

Properties.—Notwithstanding the advance made in all the practical sciences within the last few years, there is still a doubt as to the causes that produce the setting and hardening of lime and cement mortar. The old theory was that all mortars hardened by the absorption of carbonic acid from the atmosphere, and it was supposed that, in time, the quantity absorbed would equal that expelled in burning, so that the mortar would revert to its original carbonate, and become again a limestone. It is true that rich limes will not set without carbonic acid. The mortar in the inside of a bastion at Strasbourg was found, after 160 years, to be quite soft, and the same thing was observed in a masonry pillar, nine feet in diameter, at St. Peter's, Berlin, its age being 80 years. It has also been found by experiment that a mortar of rich lime will not set in the exhausted receiver of an air

pump. But carbonic acid alone will not perfect the hardening process, consequently it is supposed to be assisted by the crystallization of the carbonate of lime between and around the particles of the aggregates. Without such extranecus aid it is difficult to account for the hardening of mortar in thick walls. The operation proceeds from the outside, consequently every advance made is a barrier to the next in so much that it excludes the air from the softer mortar inside. There is every reason to believe that hydrate of lime, when exposed to the atmosphere, will revert to its original carbonate; but the process is such a slow one that it may be almost classed with the geological epochs. The oldest mortar in the world, that from a Phœnecian temple in Cyprus, is still far short of the ingredients it possessed when a limestone.

The induration of hydraulic mortars is attributable in a small degree to the same causes as affect the rich ones, but principally to the formation and crystallization of complex silicates of lime and alumina, the precise nature of which is imperfectly understood. It is quite evident that the absorption of carbonic acid has very little to do with the setting of hydraulic mortar, for against its slow action, already noticed, we have the fact that large blocks of cement concrete harden uniformly to the consistency of stone in a few months under water, which proves that the setting property is inherent, and not the result of external influences.

The treatment they receive in burning has a considerable effect on the quality of limes and cements of all kinds, but more particularly on those that

are only moderately hydraulic. Under burning has been known to impart a spurious hydraulicity to rich limes, and over burning occasionally destroys that property in cement, but as a rule there is little trouble in obtaining maximum results with these extreme classes. The burning of hydraulic limes is a much more delicate operation, the niceties of which can only be acquired by long experience in the art generally, and considerable practice with the actual materials that are to be operated on.

Use of Aggregates.—As already indicated, the ordinary aggregates are essential to the induration of rich limes, but in the higher hydraulic varieties, and in cements, they are simply dilutents. As rich limes do not possess the faculty of expelling any excess of moisture with which they are in contact, it is advisable to employ a porous aggregate, such as the sands produced by aluminous and calcareous rock, but when the aggregate is only employed to weaken the mortar by making it go further, there is little danger in using hard silicious sand, provided it is free from earthy impurities; indeed, this is an indispensable condition in all aggregates. It has been ascertained by experiment that the best proportion of sand for rich limes is $2\frac{1}{2}$ to 1, and for ordinary hydraulic limes $1\frac{3}{4}$ to 1. This explains the partiality of builders to rich limes. It will, in their own phraseology, "carry more sand," which means that strength and comfort are sacrificed for an insignificant saving in cost.

Strength.—In order to institute a comparison between the various articles under discussion, I give the following table of tensile strength per square

inch in pounds on limes, cement, and mortar, one year old.

Cement and Limes unmixed.

Portland cement	500 pounds
Roman ,, ...	185 ,,
Good hydraulic lime	170 ,,
Ordinary ,, ,, ...	120 ,,
Rich lime	40 ,,

Mortars.

Portland cement with 1 of sand...	310 pounds
,, ,, ,, 2 ,, ...	205 ,,
,, ,, ,, 3 ,, ...	140 ,,
,, ,, ,, 4 ,, ...	100 ,,
,, ,, ,, 5 ,, ...	50 ,,
Good hydraulic mortar	140 pounds
Ordinary ,, ,, ...	85 ,,
Good mortar of rich limes ...	50 ,,
Bad ,, ,, ,, ...	20 ,,

CHAPTER II.

Geographical Distribution.

Limestones.

IT was shown in a former paper that limestone, as a geological formation, occupies an immense area of Otago, but it does not follow that the supply of lime for industrial purposes is equally extensive, many of the calcareous rocks being incapable of producing lime of good quality. There is, however, no scarcity of lime suitable for building and agricultural purposes through-

out the province. It is known to exist in considerable quantities in the following districts —Oamaru, Otepopo, Waihemo, Maniototo Plains, Waikouaiti, Lower Harbour, Peninsula, Waihola, Waimea, Winton, Aparima, Waiau, and Wakatipu. These localities are so widely dispersed that we may safely calculate on a supply being available for any demand that can arise.

Cement Stones.—The only natural cement hitherto discovered in Otago is the well-known Septaria or cement boulders of the Moeraki district, which resemble in every respect the English stones from which Roman cement was originally manufactured. According to Dr. Haast, the boulders follow the coast from Shag Point to the Terapupu Creek, thence run in a straight line to the Little Kuri Creek, which is struck at a point about half a mile from the sea. In the first four miles the deposit is a mere line of boulders lying on the beach or imbedded in the cliffs, but on leaving the coast it expands into a belt from 20 to 30 chains wide and $5\frac{1}{2}$ miles long.

Clays.—Many of the volcanic clays that exist in such profusion along the sea-board from Saddle Hill to Oamaru possess cementitious properties similar to the Pozzuolanas of Italy and the Tyrass of the Rhine, but as they are only used in combination with lime, they will be considered along with the other aggregates, or as a component part of artificial cement.

Aggregates.—The aggregates proper consist of shingle, gravel, and sand, which have an almost universal distribution throughout the Province.

CHAPTER III.

Analyses.

THE subjoined Tables Nos. I. to IV. give the analyses of the principal lime and cement stones hitherto discovered in Otago, together with English and foreign types. They are arranged into the four classes already referred to, viz.—1st, Rich Limes; 2nd, Poor Limes; 3rd, Hydraulic Limes; and 4th, Cements. A large number of the analyses of Otago stones are from the Jurors' Report of the New Zealand Exhibition and the publications of the Colonial Museum, but all the recent ones are by Professor Black, to whom I am very much indebted for assistance in investigating this subject. Under his direction fifteen analyses of limestones and clays were made specially for the purpose of this paper by Mr. P. S. Hay, M.A. These analyses were done with great care and accuracy, and in the most exhaustive manner, consequently they form a valuable contribution to our information on one of the most important Colonial resources.

CHAPTER IV.

Rich Limes.

Types.

EIGHT examples of English and Foreign types are given in Table I., they range in purity from statuary marble, a pure carbonate of lime, to the carboniferous limestone of Whiteford, in Wales, that has ten per

cent. of impurities. It will be observed that ordinary white chalk approaches next to marble in purity, it only contains ½ per cent of foreign ingredients.

Otago Stones.—Analyses are given of fifteen Otago limestones that furnish rich limes, which shall now be considered seriatim.

No 9 is a white, compact, crystalline stone from Southland, locality unknown, probably Winton. Its constituents are 98·80 per cent. of carbonate of lime, and 1·20 per cent. of soluble silica. It is thus entirely worthless as a cementing material.

No. 10. A compact crystalline stone of faint yellow colour from Winton, evidently closely allied in all its essential properties to the preceding one, and equally deficient in cementitious qualities. I believe that these two specimens are fair samples of the stone in the vicinity of Lime Hills, Winton, of which there are about 1,000 acres.

No. 11. Fossiliferous, compact, and very hard stone of a dirty yellow colour from Kakanui. This specimen was analyzed by Professor Black for Mr. Cairns. It contains 98 per cent. of carbonate of lime and magnesia, and 1½ per cent of sand, consequently must be placed in the same category as the Southland limes. The stone is burned extensively for building purposes, so I am sure the houses in which it is used cannot be very dry.

No. 12. Yellow fossiliferous stone from the Oamaru district, the precise locality unknown. It is referred to by Dr. Hector as a stone largely employed by Mr. Hutcheson for burning into lime. From the analysis and description given it must be closely allied to the preceding specimen.

No. 13. Soft fossiliferous stone from the eastern side of Waihola Gorge, white in colour, granular in texture, and very absorbent. This is not so abundant nor so much used as the hard variety No. 16.

No. 14. Yellow lithographic stone from the Oamaru district. It has all the external appearance of a lithographic stone, but does not exist in large quantities; it is found associated in the same rocks with No. 12.

No. 15. Grey and yellow travertine limestone of a porous texture from the Dunstan Gorge. This stone, which is sometimes called calcareous spar, is framed by the deposition of lime held in solution in the water of streams and springs. The water acquires the lime in flowing over or through rocks containing this mineral, and it is deposited in concretionary masses on the banks. Travertine is found in the small creeks that flow into the Clutha and Kawarau rivers between Roxburgh and the Shotover. This stone was first burned for lime in 1864, when it was used in the masonry of the Gentle Annie Bridge. Most of the houses in the Clutha Valley are built with mortar of this lime. I might remark that many of the famous buildings of ancient Italy are built of Travertine, notably the Colosseum. I have not seen any of the Otago deposits sufficiently hard and compact to be used as building stones.

No. 16. White, compact, and very hard stone from Waihola. This is the stone from which the well-known Waihola lime is produced. It exists in large quantities in available positions on both sides of the gorge through which the railway runs. The

rock is very much shattered and dislocated, few of the horizontal joints being more than six inches apart. This facilitates quarrying and breaking, and to some extent balances the excessive hardness, which otherwise would be a great barrier to cheap working. I regret that the Waihola limestone cannot be pronounced good, as, from its favourable situation, it would be an immense boon to Dunedin and the surrounding districts. The limestone contains 94½ per cent. of carbonate of lime, which is decidedly too rich for building in a damp situation, or where strength is required. This, and analysis No. 13, by Dr. Hector, are copied from an old advertisement of Mr. Croft's; they refer to specimens taken from the eastern side of the gorge, but I believe the stone now used, on the western side, is equally pure with No. 16. Indeed, it was lately stated in the papers that it contained 98 per cent. of carbonate of lime, which, if correct, makes the matter still worse.

No. 17. Grey granular stone from Oamaru, found in the same locality as Nos. 12 and 14. It contains 2½ per cent. less carbonate of lime than the former, and is therefore so much better in quality.

No. 18. Bluish-grey compact stone from Dowling bay. This is a sample from the top seam. Although a rich lime, it contains small quantities of all the ingredients that give hydraulicity with little sand, consequently it will make fair mortar for ordinary work in a dry situation. It forms one of five beds of limestone that occur at Dowling Bay, Lower Harbour, the particulars of which will be given further on.

No. 19. Fawn coloured, incoherent, and absorbent stone from Aparima, in Southland. It contains 92 per cent. of carbonate of lime, and $5\frac{1}{2}$ per cent. of insoluble matter, the precise nature of which is not stated. As the chances are that this is not all sand, we may pronounce the sample a good lime of its class.

No. 20. Compact grey stone from Few's Creek, Lake Wakatipu. According to the analysis, this sample contains $4\frac{1}{2}$ per cent. of insoluble matter not detailed out, but Dr. Hector says that this consists of black sand, iron pyrites, and bituminous matter, in which case the quantity of sand must be inappreciable. The stone will yield lime suitable for ordinary building purposes in the dry atmosphere of the Lake district in which it occurs. Another specimen of stone from this locality was analyzed by Professor Black, with the results given in item No. 16, Table II. It contains $12\frac{1}{2}$ per cent. of sand, so I had no hesitation in putting it in the class of poor limes. There is nothing strange in the discrepancy between the two analyses. They may both be correct, although the samples had been collected within a few feet of each other. Impure limestone deposits all over the world have the same character of irregularity in composition between the various strata. The difference may therefore be accepted as a favourable indication of the quality of the Wakatipu limestone. In all probability the intermediate beds will produce strong hydraulic limes. In his "Geology of Otago," Professor Hutton estimates the thickness of the calcareous deposits in the vicinity of Few's Creek at 600 feet, and reports the

existence of similar rock at Afton Burn, on the west side of the lake, and at Stony Creek, on the Upper Shotover.

No. 21. Bluish compact stone from the Horse Range. This stone belongs to the higher class of crystalline limestones, such as partake of the character of marbles; indeed, it merges into true marble in many places. The deposit occupies a large area of the western side of the range, near Palmerston, in accessible situations for working. With proper treatment this stone would yield a lime suitable for the ordinary purposes of the house builder. The analysis shows a deficiency of alumina, which indicates slow setting, but its ultimate induration is not thereby affected.

No. 22. Grey shelly limestone from Southland, locality unknown. Although the analysis is not complete, it shows this to be a very good lime of its class, probably the best hitherto discovered in Southland.

No. 23. White granular stone from the Oamaru district. This is the well-known building stone. So far as can be judged from the analysis, it would furnish a much better lime for building purposes than the stone usually burned in the locality.

CHAPTER V.

Poor Limes.

ANALYSES of two foreign and nineteen Otago stones that furnish poor limes, are given in Table II. This Table is introduced more for the purpose of showing those stones that are to be avoided, than as a basis for the consideration of their properties. It will be observed that with the exception of No. 16 from Wakatipu, all the stones contain upwards of 20 per cent. of silica in the form of sand, consequently their character as poor limes is fully established. The great majority of the samples are from what may be termed the Caversham stones, varieties of which occur at Waihemo, Waikouaiti, Upper Harbour, and Kaikorai.

No. 12 is a portion of a Moeraki boulder analyzed by Professor Black, and found to contain 21·00 per cent. of sand.

No. 18 is the grey building stone that overlies the white limestone on the eastern side of Waihola Gorge. Although objectionable in a cementing material, the excess of sand is an advantage when the stone is used for building purposes. It is worthy of note that instead of being black, as might be expected from the appearance of the stone, the sand it contains is found to be pure white.

No. 16 above mentioned is a compact dark stone from the same locality as No. 20 in the class of rich limes. It has been referred to at some length in considering the properties of the latter, but I might

add that possibly the presence of $12\frac{1}{2}$ per cent. of sand is not sufficient to neutralize the other good qualities. If it were entirely absent the composition of the stone would resemble that of the English ones, which yield quick setting Roman cement.

CHAPTER VI.

Hydraulic Limes.

General.

WE now come to the consideration of the most important branch of the whole subject, that of hydraulic limes, and in doing so you should be reminded that its importance does not arise from the simple fact that lime has the faculty of hardening under water That is mainly useful in being the test by which the character of the material is established. In displaying this property we know that it is an hydraulic lime, and as such, possesses a certain degree of strength, and certain powers of resisting moisture, which render it infinitely superior to the richer sorts. Even now, when the manufacture of Portland cement has reached a high stage of perfection, we find the blue Lias limes of England used in the Liverpool docks, and on the other hand no building of any pretensions to stability or comfort is erected with common or rich mortars. Hydraulic lime is therefore more capable of universal adaptation than any other cementing material we possess.

Types.—Table III. gives the analyses of three English and seven foreign limestones that yield hydraulic limes of varying strength. The former are from the blue Lias limestones, an extensive geological formation that extends diagonally across England from Dorset to York. They are undoubtedly the best in the Old Country, and have been extensively used in all the principal engineering works there. The Eddystone and Bell Rock lighthouses were built with a mortar of Aberthaw lime (No. 2) and Pozzuolana. The blue Lias lime of Lyme Regis (No. 5) was used in the London docks, and that from Holywell (No. 10) is still preferred to cement at the Mersey docks, Liverpool, where it is made into mortar with two of sand and one-third of smithy ashes. Recent experiments show that this mixture is only a tenth weaker than Portland cement mortar made with three parts of sand, which is the usual proportion for similar work. Although not shown directly by the analysis, Professor Black calculates that the Holywell stone contains about nine per cent. of silica in the form of sand.

The best known of the foreign hydraulic limes in the table is the Theil stone from Ardeche, in France (No. 4). Perhaps there is no other hydraulic lime in the world that has been so much used in exposed marine works as this one. The harbour works at Algiers, Marseilles, and Port Said, all bear testimony to its high character. It has been 20 years in the sea at Algiers without showing symptoms of deterioration; and Mons. Vicat, the great French authority said that Thiel limestone was the only one he knew that would unquestionably yield

a mortar indestructible in salt water. The cementitious properties of this lime have been subjected to a severe test at Port Said breakwater. It is used with fine sand in making large concrete blocks like those at Oamaru. Sand of this kind by itself is not a particularly good aggregate, and the blocks have to stand very rough treatment, as they are thrown into the sea, instead of being lowered gently by machinery. My apology for referring to these foreign materials at such a length, is, that we have hydraulic limes in Otago that are, so far as chemistry can determine, identical with them in all their essential properties. In fact, there is no difference in the composition of the two articles, the discrepancy in the analysis being in all cases within the limit of error claimed by the best analytical chemists.

Oamaru.—No. 11. Yellowish white conglomerate stone of a hard compact texture, found $3\frac{1}{2}$ miles south of Oamaru. Dr. Hector's analysis is not quite exhaustive, as the soluble silica is not estimated. It is evident, however, there must be a certain quantity of that base in combinatian with the alumina, in which case we may assume the lime to be feebly or moderately hydraulic. I have no information as to the exact locality of this deposit, nor as to whether it is used for mortar, but I have no hesitation in pronouncing it the best lime for building purposes hitherto discovered in North Otago. It is very much superior to the lime in common use from the Kakanui kilns.

Peninsula and Lower Harbour.—All the other Otago limestones in Table III., are from the Penin-

sula and Lower Harbour Districts; they seem to be members of one large deposit that extends from Seal Point, on the southern side of the Peninsula, to Dowling Bay, on the northern shore of the Lower Harbour. It is near the surface from the ridge south of Mr. Macdonald's kilns, to the gully at Harbour Cone; appears again at the head of Hooper's Inlet, and for the last time on Mr. Dodson's property in Dowling Bay, right across the harbour. The breadth of this reef or dyke is unknown; probably it is not more than half a mile, and the aggregate thickness of the seams now visible is at least 70 feet. There are five or six distinct beds of varying quality and depth; as a rule, they are well defined, particularly near the upper and lower sides, but occasionally more than one kind of stone is found in the same stratum. Mr. Macdonald, of the Peninsula kilns, the highest on the reef, only counts four beds, while Mr. Robertson, of the Glenmore kilns, which are situated on a much lower level, shows six tolerably distinct specimens from as many different layers. Two of them are, however, so thin, that they can scarcely be called beds, and it is also quite possible that they exist in a less marked degree in the upper quarry. There are five well defined seams at Dowling Bay, four of which have been analyzed, viz.—one, two, three, and five, counting from the top. The fourth, which is 20 feet thick, was partially analyzed, but, being found to contain 28·13 per cent. of sand, it was useless to proceed further. Whether regarded as to structure, consistency, general appearance, or chemical composition, these Otago rocks exhibit all the peculi-

arities of hydraulic limestones of no mean order. Still, as the best authorities recommend a practical test also, I applied it, and the result is equally satisfactory. Mr. Macdonald, at my request, kindly burned samples of what I considered hydraulic stone. As was expected, the lime would not slake in the usual way, and it was pulverized by grinding in a chaff-cutter and sifting through a cloth. In consequence of other engagements I could not complete the experiments at that time, so the lime lay for eight months in a state of powder, which is not calculated to improve its setting properties. There happened to be a parcel of English blue Lias lime at the time, in Dunedin, so I tested it and the ordinary rich kind from Waihola, along with the hydraulic sample from the Peninsula. All the three kinds were submitted to the same treatment and tested together. They were made into mortar neat, and and with a mixture of two parts of sand; one set was left to dry in the air, and the other placed at once in water. So far as could be determined by mere inspection, the action of the indurating process was parallel in the English and Peninsula limes; perhaps it was a little more energetic in the former, but the difference, if it did exist at all, was scarcely perceptible. The wet samples of unmixed limes had expelled the surplus water they contained—which is what is technically known as having "set"—in three days, and in fourteen days they had acquired the consistency of soft bricks. The pure samples in air hardened without cracking, and were comparatively insoluble in water on the fourteenth day. On the other hand, the Waihola limes

in water never set at all; they were softer on the fourteenth day than when immersed, the pure sample in the air cracked and crumbled in setting, and all the air samples were quite soluble. The above results, taken in connection with the chemical test, place this sample of the Peninsula limes in the class of "eminently hydraulic," as fixed by the best authorities.

Nos. 12 and 13. Dark fawn, compact stone, analyzed respectively by Drs. Hector and Black, evidently refer to the same article; the stone occurs associated with No. 15 in the second highest bed at Macdonald's quarries. As will be seen from the table, this stone closely resembles the blue Lias of Aberthaw, in Wales, their essential constituents being as follows:—

	Aberthaw Stone.	Peninsula Stone.
Carbonate of Lime	86·20	86·05
Clay	11·20	11·67

The Otago specimen has $2\frac{1}{4}$ per cent. magnesia in addition, but this is not a fault. Mr. Armstrong, of the Railway Department, informs me that the dark Peninsula stone resembles in appearance the hydraulic limestone of Burdie House, in Midlothian.

No. 14. Drab granular stone from the lowest seam at Dowling Bay. This corresponds in quality with the second highest bed at the Glenmore quarries on the Peninsula, of which Professor Black made a partial analysis. It should yield a very good hydraulic lime, for although it may be some-

what deficient in the ingredients that ensure hydraulicity, it is absolutely free from those that are supposed to have a contrary effect.

No. 15. Fawn-coloured compact stone, from the second highest stratum at the Peninsula kilns. The resemblance between this and the famous Theil limestone of France is very remarkable, as will be seen from the following abstract of their principal ingredients :—

	Thiel.	Peninsula.
Carbonate of Lime and Magnesia ...	82·36	82 03
Clay	14·90	14·29
Oxide of Iron	1·70	2.80

No. 16. Yellowish compact stone from Portobello, analyzed by Dr. Hector. The exact locality is not stated, but in all probability it is from the Peninsula or Glenmore quarries. A partial analysis, by Professor Black, of the lower seam, at the latter place, gives precisely the same quantity of carbonate of lime. The proprietor says that 22 feet of this bed has been laid bare without coming near the bottom. Although not shown in the table, there is little chance of much deleterious matter being in this stone, so it may be set down as capable of furnishing very good hydraulic lime.

Nos. 17 and 18. Specimens of compact stone from the top seam at Macdonald's, and the third at Dowling Bay. Although somewhat different in colour, these stones are almost identical in composition, and, as will be seen from the following state-

ment, they resemble closely the hydraulic limestones of Lyme Regis of the Dorsetshire Lias :—

	Lyme Regis Stone.	Peninsula Stone.	Dowling Bay Stone.
Carbonate of lime and magnesia	79·20	79·95	79·67
Clay	17·30	16·54	18·89

Nos. 19 and 20. Fawn-coloured stone, from the third seam at Dowling Bay, and the lowest at the Peninsula quarries. These again are practically the same, and they find an English prototype in the blue Lias of Holywell. Judging from the analyses, the products of this bed might fairly be called cement stones. They are in the highest class of hydraulic limestones, and seem to have all the attributes of a natural Portland cement. Their points of resemblance to the English materials are shown in the following table :—

	Raw Material of Portland Cement.	Holywell Stone.	Dowling Bay Stone.	Peninsula Stone.
Carbonate of lime and magnesia	69·87	72·90	71·20	71·72
Silica	20·54	20·10	19·18	18·85
Alumina	3·49	3·52	4·54	5·26
Iron	4·44	2·21	1·99	3.29
Insoluble in hot acids	...	25·27	23·70	22·80

But if we carry the comparison further, it will be seen that there is a still greater affinity between the English and Colonial articles. There is less than $\frac{1}{4}$ per cent. difference between the quantities of magnesia in the Dowling Bay and Holywell stones, and only a tenth per cent. difference in oxide

of iron between the latter and the Peninsula one. The seam of this stone at Dowling Bay is 20 feet thick, and there are also immense quantities on the Peninsula. The rock appears to be perfectly homogeneous, so there is little danger of irregularity in burning when once the proper temperature has been ascertained. If the qualities of this stone come up to my expectations, of which I have little fear, the value of the discovery to the community at large can scarcely be over-rated, and from the researches that have been made, I am confident any failure that may take place will result from improper manipulation, and not from a defect in the raw material.

Auckland.—Since the original papers were published I have had two samples of hydraulic lime sent me from Auckland. One of them was too rich and did not set under water, but the other seemed to be of a very superior quality. I tested its setting properties by keeping it immersed in water for some months. It acquired a hardness almost equal to that of cement mortar. I have not seen the analysis of this stone, but it undoubtedly possesses the hydraulic properties to a considerable extent.

Taranaki.—Mr. D. Atkinson has made hydraulic lime from a nodular limestone of a blue and yellowish grey colour, found in Taranaki. According to Dr. Hector it contains:—

Silicious matter—sand and clay ...	29·34
Soluble silica	1·99
Carbonate of Iron, with a little free Oxide of Iron	15·24

Alumina	0·92
Carbonate of Lime	36·68
Carbonate of Magnesia	15·33
Alkalies soluble in acid used ...	0·30
	100·00

In the Colonial Museum and Laboratory Report for 1875-6, Dr. Hector speaks favourably of the quality of concrete made with lime from this stone, but it is not clear that the concrete had set entirely under water. The proportion of silicious matter and carbonate of magnesia being considerably greater than usual, the stone is scarcely calculated to yield a very high class hydraulic lime.

Canterbury.—The report above referred to gives the following analysis of chalk from South Canterbury, contributed to the Colonial Museum by Mr. Higginson, C.E. :—

Carbonate of Lime	84·12
Carbonate of Magnesia	2·10
Clay	12·57
Iron oxides and Alumina, soluble in acid	1·21
	100.00

This shows that the chalk should make hydraulic lime of excellent quality.

CHAPTER VII.

Hydraulic Cements.

Septaria.

HYDRAULIC cements, the fourth and highest class of material in the scale, are poorly represented in Otago. The only specimen hitherto discovered is the Septaria of Moeraki, and this is very much inferior to the two hydraulic limestones, Nos. 19 and 20, described in the last chapter. In fact, they should exchange places; properly speaking, the cement boulder is a limestone, and the limestone a cement rock. The present arrangement is adhered to simply because it corresponds with a time-honoured English custom. Although there are so few colonial articles to be described under this head, it does not follow that such will always be the case; I therefore give twelve analyses of English and foreign cements in the raw and manufactured states; they may be useful for reference in case further supplies of native cements are discovered. Septarian nodules or boulders have been used since the beginning of this century in the manufacture of Roman cement; they are found along the south and eastern coasts of England, from Weymouth to Lowestoft, and at several localities inland. There are also solid masses of similar stone at Harwich, in Suffolk, and Calderwood, in Lanarkshire. The Septarian boulders are well dispersed over the Conti-

nent of Europe, and cement rock occurs in France and the United States of America. That of Boulogne, in France, approaches next in quality to the artificial Portland cement; it is found in a thick stratum 160 feet below the Septarian beds, and is sufficiently soft to be excavated with pick and shovel.

There is comparatively little risk in manufacturing cement from a solid, homogeneous stratum of the raw material, but it is almost impossible to get uniform results from Septaria; a glance at one of our Moeraki boulders is sufficient to demonstrate this. It will be seen that the core is almost pure lime, and the exterior of the ball nothing but clay; while in many cases the quantity of lime is equal in different sized boulders. Dr. Hector analyzed the whole mass of the nodule, including the calcareous veins, and found it to contain $72\frac{1}{2}$ per cent. of carbonate of lime, but freed from the veins the yield of lime was only 59 per cent. The stone in No. 13, Table IV., should furnish an eminently hydraulic lime, but the produce of No. 12, Table II., which, Professor Black says, is a fair representation of the Moeraki boulders, would be a poor lime of very inferior quality.

Experiments.—Practical experiments made with cement from Moeraki boulders, are equally irregular and unsatisfactory. Mr. J. T. Thomson manufactured a considerable quantity in 1868, and tested it against Portland cement in the following manner:—Two bricks were laid together with mortars of the two cements, and kept a month in water, and a fortnight dry. The highest results obtained were,

with Moeraki mortar, three to one, and Portland, one to one; it took 400 pounds in both cases to tear asunder the bricks. Assuming they were placed crosswise, this would give a tensile strength of 22 pounds per square inch. About the same time, Mr. G. M. Barr got an unmixed sample that stood 150 pounds in 24 days, against 110 for Portland cement under the same conditions. These comparisons are not, however, fair to the imported article, as the samples tested must have been of a very inferior quality. Instead of 25 pounds in the first experiment, ordinary Portland cement should have stood 140, and instead of 110 in the second, the resistance should have been 270 pounds. Mr. John Macgregor also tested the Moeraki cement, but the result was less satisfactory than either of the above. Two samples of mortar were made with pure cement and salt water—one was kept dry for 10 days, and the other in salt water for 87 days. Neither of them stood any measurable strain. Mr. Macgregor also noted that the samples contracted very much in setting, which indicates too much carbonate of lime. The irregularity in composition of the Moeraki boulders is so great that it would be practically impossible to manufacture cement from them of a uniform quality; one kiln might be equal to the best Portland, and the next quite worthless. We may therefore conclude that the expense of selection on the one hand, and the risk of failure on the other, are insurmountable obstacles in the way of its general utilization.

CHAPTER VIII.

Artificial Cements.

WHEN I began to investigate the subject of native cements and limes, I was under the impression that we had no stone capable of furnishing hydraulic limes, consequently some little time was devoted to the consideration of providing an artificial substitute ; but the existence of natural cementing ingredients of a high character having been fully established, the necessity for adopting the latter expedient is, to a considerable extent, removed; the subject will therefore be dismissed in a few words.

As you are probably aware, English Portland cement is made from two of the most common and abundant raw materials in the country—chalk and clay—and the manufacture is equally simple. The materials are mixed in the proportion of seven of the former to three of the latter, then burned in a kiln and pulverized, as already described. In Germany, where there is no chalk, a substitute is found in hard limestone. This entails extra labour in pulverizing the raw material as well as the cement, but the result is practically the same.

Ordinary yellow clay does not make good cement; that in common use is a dark blue unctuous variety found in tidal estuaries and swamps. Blue

clays, supposed to be suitable for the purpose, are abundant throughout the Province. A sample from the railway cutting at Caversham was analyzed by Professor Black with the following results, which are shown alongside English types :—

	Otago Clay.	English Clays.		
Silica	65·28	68·45	64·72	70·56
Alumina... ...	23·18	11.64	24·27	14·52
Iron	3.20	14.80	7·14	3·06
Lime and Magnesia	2.58	0·75	1·89	4·43
Alkalies	1·04	4·00	...	3·95
Water	5·19	...	...	...
Carbonic Acid ...	...	..	...	3·48
	100·47	99·64	98·02	100·00

These figures may not be near enough to prove that this particular Otago clay is good for making cement, but they are sufficient to show that there is every chance of getting the proper kind if required.

Portland cement is a low-priced article, the value of which is more than doubled by the charges of importation, and it can be manufactured without much skilled labour, consequently it is an industry that might well be started in New Zealand if the hydraulic limes do not come into competition with it. The best places in Otago for a factory are the Waihemo and Aparima districts, both of which furnish soft limestones and fuel, the main requisites. The soft marl found at Waikouaiti and Greytown, being supposed to contain the ingredients of raw cement, was analyzed, and gave the following result :—

Clay	27·84
Iron	11·24
Lime	24·78
Sand	35·16
	99·02

The last item neutralizes the good qualities of the others, so we pass it into the category of unsuitable materials.

The idea of utilising the rich limes induced me, some years ago, to make an examination of volcanic clays to ascertain if they contained any of the properties of the Pozzuolanas of the old world that have been used from time immemorial to mix with lime in hydraulic works. About 40 specimens of all shades of colour imaginable were collected and tested by being made into mortar with an equal proportion of lime, then kept in water for two months. Four or five samples of drab and neutral tints gave indications of being feebly hydraulic, so, possibly, a more complete investigation would lead to the discovery of a material of considerable utility. The great objection to Pozzuolanas is that, like the Moeraki boulders, uniformity of composition cannot be ensured.

CHAPTER IX.

AGGREGATES.

EXCEPT in the case of the higher hydraulic limes and cements, where the maximum strength is obtained by using them in a pure state, as much depends on the aggregate as on the cementing material, notwithstanding which, there is no article used in construction that commands so little attention. The main essentials of a good aggregate are sharpness and freedom from earth or other impurities of a similar nature. The proper size and hardness vary with the quality of the cementing material;—rich lime takes a coarse, soft sand, and cement a fine, hard one.

As no attempt had been made to determine the relative merits of the Otago sands, I collected a number in the vicinity of Dunedin, and experimented on them in the following manner, and with the results given in Table V. Each kind of sand was made into mortar with Waihola lime in the proportion of one of lime to two of sand. The lime had been air-slaked, and was sifted through a gold-dust sieve before being used. The ingredients were measured in the most exact manner, and carefully mixed with the smallest quantity of water that would give plasticity. The mortar was then used to cement ordinary bricks placed crosswise, which gave a bearing surface of about 18 square inches. After being kept in the open air for 160

days, the bricks were pulled asunder with weights increased gradually to the breaking point. It will be seen from the table that the highest results were obtained from Anderson's Bay sand, which broke with a strain of 226 pounds. About $1\frac{1}{2}$ square inches of the mortar in the inside was not quite hard. Assuming that this only supported half as much as the other portion, we make the cohesive strength 13 pounds on the square inch. Two samples of each kind of sand were tested. Taking only the highest in each pair, we find that, out of a total of 27, four broke with strains ranging from 226 to 150 pounds, nine from 150 to 100, six from 100 to 75, and six from 75 to 47, while two did not stand any measurable strain. I regret to add that many of the last three classes are constantly used in Dunedin.

CHAPTER X.

Recapitulation and Cost.

Uses.

LEAVING out the materials in Tables II. and IV., which are comparatively valueless, the following will show the various purposes for which the Otago limes are suited, each class being capable of performing the functions of those under it as well as its own:—

Rich Limes.

Nos. 9 to 14.	Whitewashing and agricultural and caustic purposes only.
„ 15 to 18.	Brickwork in partitions and plastering.
„ 19 to 23.	Low thin brick walls in a dry situation.

Hydraulic Limes.

Nos. 11 to 13.	Ordinary walling above ground.
„ 14 to 16.	Foundations of ordinary buildings, concrete, and engineering structures above ground.
„ 17 to 20.	Nearly all the higher class masonry for which cement is usually employed.

The rich limes are well dispersed throughout the Province, but the hydraulic ones are confined to the vicinity of Dunedin, unless we include the Lake Wakatipu deposits, the hydraulicity of which has not been fully proved. Although lime has been burnt on the Peninsula for many years, none of the good seams have been utilised. The proprietors inform me that there is no market for this quality. Builders will not use it in preference to the rich lime, as the latter carries more sand, and in the absence of any information on the subject, professional men and the public generally have no choice.

Comparison.—In order to institute a comparison between the various articles under discussion, I have prepared the following statement, showing the strength and cost of mortars now used in Dunedin, together with an estimate of other kinds prepared from the hydraulic limestones :—

Variety of Mortar.	Tensile strength per square inch in pounds.	Cost of mortar for a cubic yard of brickwork.
Now in use—		s. d.
Portland cement with 2 of sand	205	14 6
" " " 3 "	140	11 0
" " " 4 "	100	9 0
" " " 5 "	50	8 0
Rich Lime " 2½ "	15	3 9
Estimates for new mortars—		
Weak hydraulic lime, slaked	50	4 0
Ordinary " " ground in mixing	100	4 6
Strong hydraulic lime, shell lime ground	140	7 0

In contrast to the above it should be stated that ordinary hydraulic mortar in England costs from 1s. 10d. to 2s. per cubic yard.

Judging by the quality of the ingredients, and the manner in which they are manufactured, I should not estimate the tensile strength of our ordinary lime mortars at more than ten pounds per square inch, which is less than half the strength of European mortars that are designated "bad." Their defects are quite apparent to any one who takes the trouble to examine the southern side of a building. It will be found that, after a lapse of years, the mortar, even on the surface, is often quite soft and friable. A good example which I noticed lately exists in the masonry of the Waitati Road Bridge, erected in 1869; although apparently well proportioned and prepared, the mortar in some places is still no harder than stiff clay. There is no

greater anomaly in the constructive arts than what is displayed in the use of weak mortar with strong bricks. We might as well connect plate iron with lead rivets. In designing a bridge or a roof, every part is strained alike, so there is nothing wasted; but in the case before us, three-fourths of the work is thirty times stronger than the remainder. As shown above, the cost of increasing the strength of our mortars five times is 3d., and ten times, 9d. per cubic yard of brickwork. These figures would only represent £10 and £30 on the Dunedin telegraph office, so the question of expense cannot stand in the way of the substitution of hydraulic limes for those in common use.

General.—At present the annual consumption of Portland cement in New Zealand is about 40,000 casks, representing an expenditure to the consumer of £40,000. Of this quantity I am confident that nine-tenths is used in works for which our native products are equally well adapted; indeed, with the exception of some wet tunnel lining and foundations, where quick setting was a desideratum, there have been few works executed in New Zealand that required cement. We are, therefore, spending £36,000 on a foreign article, while a native one that would serve our purpose can be obtained at half the cost. This state of affairs has resulted entirely from ignorance of our resources, and of the quality of the materials within our reach.

The principal hydraulic limestones of the Peninsula are rather inaccessibly situated; at present their only outlet is by road to Dunedin, a distance of ten miles, but a moderate expenditure on a tram-

way two miles long would connect them with the proposed Portobello Railway and the waters of the harbour. The deposit at Dowling Bay occupies a very favourable position on the beach, four miles below Port Chalmers. The new road to the Heads passes through it, and there is deep water within a few yards of the limestone rock.

In order to utilize these stores of hydraulic limes to the best advantage, I would suggest the adoption of a plan that seems to have been followed in America: The quality of the stone, not only in each quarry, but in each bed of that quarry, is so clearly determined that its name conveys a distinct meaning to professional men who stipulate for certain kinds in certain work. Gradually the names acquire a commercial value, like the brands in ordinary manufactures, and thus the public generally acquire the knowledge necessary to ensure each article being used in its proper place.

SECTION III.

TIMBERS.

CHAPTER I.

Properties of Timbers.

ALTHOUGH the properties of timbers generally are better known than those of the other building materials that have already been discussed, it is necessary, for the proper investigation of our subject, to consider the leading characteristics that bear on their economic value, and in doing so I shall trace the timber through the various stages of its existence.

Structure.—As you are probably aware, the structure of ordinary timber is, to all intents and purposes, identical with that of a brick wall: it is composed of vertical and horizontal layers, breaking joints, and cemented together in much the same way. The vertical joints, consisting of the annual rings and medullary rays, are quite clear and distinct; but the horizontal ones, made from the

interlacing of bundles of woody fibre of irregular lengths, are only visible to the microscopist. It is this difference in the length of the scarf, or joint, that makes splitting timber so much easier than cutting it across the grain. The concentric rings represent the growth in a year or season; they are generally very distinct in timber grown in a cold climate, where there is a decided period of repose in the vegetation; but in many tropical trees the rings are scarcely discernible, and some botanists allege that occasionally so many as four rings are formed in one year. The medullary rays are thin plates of woody matter that radiate from the pith to the bark, and form the weft which interlaces with the warp of the annual rings. Although believed to exist in all timbers, these rays cannot be traced in the firs and pines of the Old Country, but are very conspicuous in oak, beech, and other hard woods; this rule does not hold good in Otago, for there are few timbers, hard or soft, in which they do not appear. These medullary rays are what give the peculiar watered figure called silver grain, which is so much prized by cabinetmakers and other manufacturers of fancy wood-work.

Growth.—The principal agent in the formation and development of woody fibre and tissue is the sap, which performs the same functions in plants that blood does in animals. After being extracted by the roots from the soil, it rises through the trunk to the leaves, and is there subjected to certain chemical changes that fit it for the formation of timber. In saplings, the fluid permeates and rises through the whole trunk; but in old trees with

solid heart-wood, it is confined to the sap-wood and the bark. At this stage the heart-wood contributes nothing to the other parts of the tree except in supporting them. The leaves are the lungs of the plant, but, instead of making the original fluid thinner and purifying it by the extraction of carbonic acid and the addition of oxygen, as in animals, they make the sap thicker, and *add* carbonic acid, which is the food of plants. The precise nature of the chemical process carried on in the leaves, and the exact constituents of its product, are imperfectly understood. After the sap has acquired the necessary ingredients, it returns through the outer layer of the wood and the inner layer of the bark, leaving in its course a deposit of ligneous matter on each, and permeating, to a greater or less extent, all the rings of sap-wood. The deposits made on the bark and wood harden into rings of timber and bark, the former to increase the size of the tree, and the latter to replace the scales that are continually falling off the outer surface. The conversion of sap into heart-wood is attributed to the combined action of the juices and the compressive force exercised by the shrinkage of the outer rings and bark; but against this idea we have the fact of the change being generally sudden: one ring may be perfect heart, and the next sap-wood of a very inferior quality. Whatever be the cause of this ripening of the timber, the process is not simultaneous with its growth, for the rings of sap-wood always decrease in number as the tree approaches maturity, and there are frequently fewer rings on one side than the other.

Climate, situation, and soil exercise a great influence on the character of timber. Among different trees the best timber is obtained from tropical countries, but in the same species the product of cold climates is found to be the strongest and most durable. Most authorities, ancient and modern, pronounce in favour of slow growth in timber trees as essential to perfection; but I find that Mr. Laslett, Inspector of Timber to the Admiralty, entertains an opposite opinion, formed from observations on oak and fir trees. I can easily understand the possibility of rapid growth being conducive to strength and durability, as it proves that the plant is well fed and in vigorous health. Although the wood may be soft and porous in the young tree, it does not follow that the old one will inherit these qualities; the energy that puts forth vigorous shoots is in all probability sufficient to provide them with a proportionate supply of woody fibre and the other essentials of strength.

Timber grown in open ground is stronger and more durable than that from the dark forest, but, on the other hand, it is more subject to twists, shakes, and irregularity of composition, and the trees are often stunted and crooked. The effect of the weather is well shown on the southern side of the Otago Peninsula, where the trees are blown into shapes as grotesque as could be seen in a Dutch garden.

The influence of situation and soil on the growth of trees is very remarkable, as the following table, compiled from the "Forester," will show. It gives the diameter in inches, at eight feet from the

ground, of various kinds grown in favourable and unfavourable situations :—

	Favourable Situations.	Unfavourable Situations.
Oak, 80 years old ...	$31\frac{1}{2}$ inches	$11\frac{1}{2}$ inches
Scots Pine, 50 " " ...	17 "	$7\frac{1}{4}$ "
Larch, 35 " " ...	17 "	8 "
Spruce Fir, 35 " " ...	15 "	6 "

Felling.—One of the most important considerations in the cultivation of timber for building purposes, is the time at which it should be cut—first, the age of the tree, and next, the season of the year. The desideratum in the first instance is the zenith of growth—when maturity has been reached, and the decline not begun; and, in the second, when the tree contains the minimum of sap. Unripe timber is soft, sappy, and liable to decay; and, when too ripe, it is brittle, and decay has already commenced at the heart. There is comparatively little difficulty in judging as to the ripeness of timber; when the top shoots cease to grow vigorously, and the branches become stunted and thick, it is ready for the axe. The following are given in various works as the ascertained ages of the common English trees :—

Yew	... ...	1,214 to 2,820 years
Lime	... ...	1,147 "
Oak	... ...	810 to 1,500 "
Larch	... ...	576 "
Elm	... ...	335 "

As a further indication of their ages, Mr. Laslett

gives a very complete list of the known timber trees throughout the world, with the number of concentric layers in an inch of an ordinary-sized specimen. I subjoin a few of the more common varieties :—

English Oak, fast grown ...	1·50
„ Elm, „ ...	1·50
Cedar, Honduras	1·95
Elm, English	2·80
Beech, „	2·83
Oak, „	2·84
Ash, „	2·90
Mahogany, Honduras ...	3·20
Blue Gum, Australia... ...	3·30
Teak, Moulmein	4·00
Iron Bark, Australia... ...	4·00
Pine, Oregon	4·32
Greenheart, Demerara ...	4·60
White American Oak ...	4·70
Fir, Dantzic	4·82
Pine, Yellow, Canadian ...	5·22
Ash, American	6·36
Kauri, New Zealand	6·70
Spruce Fir	11·40
Elm, Canadian	14·00

There is a considerable difference of opinion as to the proper season for felling timber; while all authorities are agreed in considering it to be the time when there is least sap in the tree, the time itself is not decided. One party argues that as vegetation is suspended during winter, there must be little sap in the timber : but the other maintains that midsummer is the best season for felling, as all the juices that rise in spring are then expended in forming leaves. With deciduous trees, and in a cold climate,

the chances are greatly in favour of winter felling, but with evergreens and in a warm climate, there seems little choice between summer and winter. Of course there is a very marked difference in the quality of timber felled in winter and spring, and in summer and autumn. Experiments made in Germany to settle this point gave the following results: Timber cut in December was impervious to water end-wise; in January a few drops percolated through in 48 hours; in February two quarts went through in that time; and the March cut timber allowed two quarts to run through in two and a half hours. It is to be regretted that these experiments were not carried over the whole year, as the result would go a long way towards deciding the relative merits of winter and summer felling. Notwithstanding the fact that spring is admitted on all sides to be the worst season of the year for felling timber, it is the one in which the "indestructible" English oak is cut; this is in consequence of the bark, which is used for tanning, being more valuable when the sap is rising. Summer is considered the best time for cutting alder and beech in England; it is also the season in which oak is felled in Italy, and pines in Germany.

The ancients believed that the moon had a ripening influence on timber, consequently it was felled during her last quarter. The same belief was embodied in the Code Napoleon, and prevails to this day in the forests of Germany and Central America. It has a commercial significance in the latter place, for mahogany that is guaranteed to have been cut during the proper phase of the moon commands a

higher price than any other. This lunar influence is probably quite imaginary, but when we consider the effect of the planet's attraction on the ocean, it is not unreasonable to suppose that vegetable juices may be attracted in a similar manner; at the same time we would expect a manifestation twice a month, as in the tides, instead of once only.

Qualities of Timber.—The chief attributes of good timber are a minimum amount of sap-wood, compactness of texture, and depth of colour, where colour exists. The proportion of sapwood varies in trees of different ages and kinds; chestnut, fifteen and a half inches diameter, has three-eighths of an inch of sap all round; oak, seventeen inches diameter, has one and a quarter inches of sap; and Scotch fir, twenty-four inches diameter, two and a half inches of sap. The ordinary defects in growing timber are the shakes, or cracks and hollows that appear in the heart of full grown and over ripe trees. A small straight crack in the centre of a log does little harm, but when it is of a star shape, and has a twist in the length of the timber, the transverse strength is seriously impaired, and it cannot be cut into planks. Another defect, known as the cup shake, consists in want of cohesion between the annual rings; it is less common but more serious than the one just described. The heart cavity is caused entirely by over ripeness in the trees, and its extent is in direct proportion to the time they have been allowed to stand after maturity. The cup shake is rare in Otago, but the other two defects occur in several kinds. A straight heart crack filled with gum or resin is very common in rimu,

and the hollow heart is always met with in aged totara and cedar.

Seasoning.—There is no operation connected with the utilizing of timber on which so much depends as seasoning, at the same time there is no subject that receives so little attention from practical men, particularly in new countries. When it is considered that proper seasoning doubles the strength of timber, and increases its durability to an indefinite extent, the folly of using it in a green state is too apparent to need comment. Barking the trees a few months before felling, which is a very old custom, assists materially in draining the sap, and if to this is added the cutting through of the sap-wood all round, it makes the process very complete. Barking, as a means of seasoning, is practised to some extent in the North Island, but I never heard of its being resorted to for this purpose in Otago. After felling, timber is seasoned naturally by the weather, or artificially by steeping in water, smoking, boiling, steaming, or drying in a warm atmosphere. The object in all cases is to abstract such portions of the sap as are calculated to cause decay, but in doing so there is a danger of going too far; the juices that give elasticity, toughness, and durability may be abstracted along with those of a pernicious kind. It is found that natural seasoning is the best, and next to it, that by steeping the timber in running water, but both are very much slower than any of the other methods named. According to Laslett the time required for seasoning timber in open sheds is as follows:—

Pieces	12 to 16 inches,	Oak 14 months,	Fir 7 months
„	8 to 12 „	do 10 „	do 5 „
„	4 to 8 „	do 6 „	do 3 „
„	2 to 4 „	do 4 „	do 2 „

The same sizes of timber would be equally well seasoned by steeping for ten days in running water, and afterwards drying under cover for a month. The other methods of seasoning complete the work in a few hours and upwards, but what is gained in time is frequently lost in strength and durability; the only real benefit they bestow is the saving of shrinkage.

The amount of moisture contained in the ordinary English timbers is shown by the following table :—

	Weight in pounds per cubic foot, when green.	Weight in pounds per cubic foot, when seasoned.
Oak	77	52
Ash	65	50
Beech	65	50
Elm	70	48
Fir	54 to 74	31 to 41

The ultimate transverse shrinkage in the seasoning of boards twelve inches square and half an inch thick, is found to be for oak, $\frac{1}{12}$ the breadth; Riga fir, $\frac{1}{32}$; Virginia pine, $\frac{1}{27}$; larch, $\frac{1}{27}$; elm, $\frac{1}{24}$; kauri, $\frac{1}{64}$.

Decay and Preservation.—The causes of decay in timber are of three kinds :—1st. Chemical decay—a natural decomposition by the action of the air and moisture; 2nd. Vegetable decay or dry rot, a

decomposition that takes place through the growth of fungi; and 3rd. Animal decay—waste by the destruction caused by worms and insects. The first of these is, to all intents and purposes, a slow combustion, effected by the acids of the atmosphere, and greatly accelerated by changes from wet to dry. Most timbers will last a long time if kept constantly wet or constantly dry in an equable temperature, but the best only will stand exposure to severe alternations from wet to dry; the most trying situation for timber in this respect is in posts in the ground, decay always attacks it first at the surface. I am not aware of any cure for this natural decay; charring, painting, or tarring will retard its progress, but the only safe course is the use of a durable timber well seasoned. In connection with this I may notice a practice that exists among our settlers of inverting posts when putting them in the ground, to increase their durability; like the lunar influence already noticed, this was long thought to be only an imaginary benefit, but lately the matter has become an established fact. Experiments made in England on oak posts from the same tree showed those put in the ground with the top upwards, as they grew, to be rotten in twelve years, while their neighbours that were inverted showed no symptoms of decay in sixteen years. This is explained by assuming that the capillary tubes are provided with valves which open upwards; on inverting the post these valves oppose the rising of moisture.

The relative durability of the timbers in common use in England has been ascertained by inserting

pieces $2\frac{5}{8}$ inches square into the ground; they decayed in the following order:—

Lime, American Birch, Alder, and Aspen	3 years.
Willow, Horse Chestnut, and Plane ...	4 "
Birch...	5 "
Elm, Ash, Hornbeam, and Lombardy Poplar	7 "

Oak, Scotch Fir, Weymouth Pine, and Silver Fir were only affected to a depth of half an inch in seven years; and Larch, Juniper, and Arbor Vitæ were not touched at all in that time.

Vegetable decay, or dry rot, is a regular disease induced in unseasoned timber by defective ventilation. In most parts of the world this is the worst enemy that timber has; we hear of ships being destroyed, and houses being made uninhabitable in an incredibly short time through its ravages, and even cargoes of timber are seriously affected on the voyage from America to England. Hitherto this disease has been little known in Otago, not because any precautions are taken against it, but simply on account of the defects in our wooden buildings, which give ample ventilation. I have seen several instances of dry rot in brick and stone buildings in Dunedin, but few in wooden ones; it is, however, very common in the timber-work of mines.

The third cause of decay in timber, that by animals, is also of minor importance in Otago; the marine animals have caused some little trouble, but the land ones are scarcely known as destroyers in material that has been used. The latter class consist of a small beetle supposed to be much the same as the English one, and the large white worm that used to be eaten by the Maoris. These beetles are

very destructive, particularly in carvings, but they are easily destroyed by fumigations; the large worm is very common in old trees lying in the forest, and I have seen it in piles that had not been barked but never in wrought timber.

The marine animals most destructive to timber are the *Teredo navalis,* or marine worm, and *Limnoria terebrans,* a small boring crab of the leech family, both of which are common in New Zealand waters. Professor Hutton finds that our *Teredo* is somewhat different from the European one, consequently it is called the *Teredo antarctica.* The *Teredo* is a worm-like animal from three to twenty-four inches in length, and from a quarter to an inch in diameter, according to the nature of the wood in which it has taken up its abode. It is furnished with a wonderful boring apparatus, like a pair of shell augurs, by which it perforates the hardest timber with astonishing rapidity. The smaller animal, which Professor Kirk says is allied to *Limnoria lignorum,* although scarcely larger than a grain of rice, is as destructive as the *Teredo.* Large numbers attack the timber and speedily destroy it by fairly eating it away; indeed, some animals of this species are able to penetrate stone.

The effectual preservation of timber in all conditions is a problem not yet solved. Oleaginous and bituminous substances retard the progress of decomposition, but, without thorough seasoning and ventilation, they are of little value. On the contrary, anything that closes the pores of the timber while containing sap, promotes decay. One of the

best preservatives of timber is the creosoting process, invented 40 years ago by Mr. Bethell, which consists in extracting the natural juices by pumping, and then refilling the pores with creosote. Timber prepared in this manner resists decay of all kinds for a long time, but on account of the inflammable nature of the preparation, and its obnoxious smell, timber that has undergone the process cannot be utilized in ordinary architectural work.

CHAPTER II.

Nomenclature of Timber Trees.

NO subject connected with New Zealand Timbers is in such an unsatisfactory state as the nomenclature. The utmost confusion exists in the names of many kinds, and there are very few that bear the same name throughout all parts of the colony. In consequence of our ignorance on this point many of the best timbers have been rejected, and inferior ones accepted in their place, a proceeding which has led to disappointment and loss, both in private buildings and public works. With the view to remedy this evil I have prepared a table (No. VI.) hereto appended, showing the various names of all the principal Otago woods. The popular name is that by which the tree is best known, whether botanical, native, or given by the settlers, and the

synonyms consist of the proper botanical name, and any native or vernacular names that have been applied to the plant. Many of the trees were formerly known by other botanical names, but the one given is now universally accepted, consequently the others are not required. The great majority of all these old botanical names can be found in "Hooker's New Zealand Flora," and "Gordon's Pinetum." As the leading colonial authorities have been consulted in preparing this table, I have considerable confidence in its accuracy and completeness. The identity of two or three of the smaller plants with some of the native and vernacular names is not fully established, but there is little or no doubt with regard to all the principal timber trees.

CHAPTER III.

Geographical Distribution and Classification.

Geographical Distribution.

ACCORDING to a return made to Parliament in 1874, Otago possesses about 2,250,000 acres, or 3,500 square miles of forest lands. With the exception of a block of 600 square miles in the north, which is almost treeless, the forests are well dispersed throughout the Province, and the largest supplies are in very accessible situations.

Practically there is a belt of forest along nine-

tenths of the Otago coast. It is quite unbroken from the north-west boundary at Martin's Bay to Riverton, a distance of 200 miles, and the gaps from thence to Waikouaiti, near the north-east boundary, are few and short. The West Coast belt extends with greater or less continuity right across the country to the Waiau valley, its resources being comparatively unknown. The timber on the seaboard is good, but that in the interior is supposed to be scrubby. There is a considerable quantity of birch in the seaboard forest from Martin's Bay to Preservation Inlet, but round the south and east coasts they consist of pines and the other common varieties. Stewart Island is one large pine forest, with a fair sprinkling of rata. Southland is remarkably well supplied with timber. A glance at the map shows an alternation of bush and open country that resembles the conception of a landscape gardener more than a natural arrangement. These isolated patches of forest embrace the whole width of the country, and extend 50 miles inland. One of the largest bushes in the interior of the Province extends along the face of the Eyre mountains from the Five rivers to the Te Anau lake, including the Mararoa district. It covers about 400 square miles. This and the Lake forests, altogether about 400,000 acres, are all birch.

The principal forests now available near the sea, in Southland, are from Riverton to the Waiau, sixteen miles long by twelve broad; and the Seaward bush, from Invercargill to the Mataura, twenty miles long, and from two to three broad. The Oto-

tara, Waikiwi, and Makarewa bushes in the vicinity of Invercargill are also of considerable extent. Following up the coast the next large forest is the Tautuku bush, extending from Waipapa point to the Clutha river, a distance of forty-five miles, and inland about twelve. We have then smaller patches at Kaitangata, Akatore, Dunedin, Waikouaiti, and Otepopo. The principal isolated bushes in the interior occur at Waipori, Tapanui, and Switzers. Except on the west coast, where it descends to sea level, birch does not exist in forests below an altitude of 900 feet.

The principal supply of provincial timber for the Dunedin market comes from Southland and Catlin's river, where the forests are accessible to water and railway carriage. Although Stewart Island is particularly well favoured in respect to harbour accommodation, its isolated situation has hitherto been a barrier to the development of the timber trade, and the west coast supplies have never been touched.

Classification.—Timbers are usually arranged into classes, according to their botanical or structural affinities and peculiarities. The most common arrangement at Home is to divide them into leafwoods and pinewoods, which keeps the hard and soft kinds separate; but this mode of classification would not have the same result in New Zealand. I shall therefore consider the Otago timbers under two heads, with the conventional names of "Hardwoods" and "Softwoods."

CHAPTER IV.

HARD WOODS.

MAPAUS.

THE trees in this family are too small to yield useful building materials; but it is important in furnishing the strongest wood in Otago; I have therefore given it the first place in the Tables. The five trees that will be considered under the generic name of Mapau are not all members of the same botanical order. The first three are *pittosporea*; the fourth—red mapau—is the only Otago representative of a large New Zealand family; and the fifth—white mapau—although belonging to an extensive order, has no immediate relatives in the colony. The mapaus are found in all the low-lying forests, and are particularly plentiful in the neighbourhood of Dunedin.

No. 1. *Black Mapau—Pittosporum tenuifolium.* A small tree, seldom exceeding 30 feet in height and twelve inches in diameter. It has pale green shining leaves and purple flowers. The wood, which is of a dirty white colour, is tough and fibrous. Mr. Balfour's experiments at the New Zealand Exhibition showed it to be nearly 90 per cent. stronger than English oak.

No. 2. *Black Mapau—Pittosporum Colensoi.* With the exception of being generally larger, this

tree is identical with the former; indeed, some authorities suppose that they are merely varieties of the same species.

No. 3. Turpentine—Pittosporum eugenioides. This is the largest of the mapau family; it sometimes attains a height of 40 feet, with a diameter of 24 inches. The bark is thin, and of a light colour, the leaves are silvery green, and the flowers pale yellow. Altogether, this is one of the handsomest trees in Otago. The bark exudes a thick gum, and the juice of the leaves, which is somewhat similar, was formerly used by the Maoris as a perfume, but I fear it is too resinous for European tastes.

The three trees above described yield a close, compact, heavy wood, hard, tough and fibrous in the grain, but much given to warping when used green. It is not durable in fencing posts, or similarly exposed situations, but answers well for rails. Hitherto this timber has not been used in constructions of any kind; it is not suitable for many building purposes, but would do for handles and implements where strength is required.

No. 4. Red Mapau—Myrsine Urvillei. This is a small tree, well known to everyone from its conical shape and dark foliage. It seldom exceeds fifteen inches in thickness, but is much prized by settlers on account of its durability and straightness of grain. The timber is strong, heavy, and compact, like English beech, but much darker in colour. Red mapau will not stand long in the ground; but, so far as ordinary decay is concerned, it seems almost indestructible in most other situations.

Many of the braces in the old Dunedin jetty, erected seventeen years ago and recently removed, were of mapau saplings three or four inches in diameter. They were nearly all in good preservation, and free from the ravages of marine worms. Slight symptoms of approaching decay were observed in the braces that had their butt ends in the water, but all others were quite sound. The timber is, however, very subject to the attacks of a small boring beetle when kept dry. Hitherto red mapau has only been used for firewood and fencing, but it is suitable for making furniture and carpenters' tools.

No. 5. *White Mapau—Carpodetus serratus.* A small tree like the black mapau, No. 1. It has mottled green leaves, and large white flowers; the wood is white and fibrous. Although its absolute strength is not so great as that of the red mapau, it is tougher, and consequently better suited for the handles of tools.

According to observations made by Mr. T. Baber, C.E., Auckland, young trees of the mapau family attain a height of thirteen to seventeen feet in ten years.

MANUKA AND RATA.

These trees belong to different branches of the Myrtle family, one of the most extensive in the world. They resemble each other in the quality and appearance of the timber and bark, but are very different in size of trunk and character of foliage; they also affect different localities and soils.

No. 6. *Manuka—Leptospermum scoparium.* This is the variety known as white manuka, which is

much smaller than the red. It grows best on stiff clayey soils that will scarcely produce anything else, but is common on the margin of large bushes in all the low-lying districts of the Province, where it acts as a breakwind to less hardy plants. This tree is best known as an ornamental shrub, but occasionally attains to a diameter of from nine to fifteen inches. Its properties as a timber are generally the same as those of the next variety, consequently they will be considered further together.

No. 7. *Manuka—Leptospermum ericoides*—Is common in isolated positions on the whole of the eastern seaboard, and occurs in considerable quantities in the vicinity of Dunedin, Purakanui, and Otepopo. The tree occasionally attains a height of sixty feet with a diameter of from two to three feet at the butt, but these are extreme sizes—logs thirty feet long and ten inches diameter at the smaller end may be considered the practical limit of workable timber. So far as habits and habitat are concerned, this tree is identical with the preceding variety. Like most other hardwoods manuka does not grow straight, and is much given to warping and cracking; but I do not know that it inherits these defects to a greater extent than is done by jarrah, ironbark, and other Australian timbers of the same class, and it is freer from heart shakes and knots.

Manuka is noted for its great strength and hardness, combined with a considerable amount of toughness. Although, as a class, it did not give the highest average, one specimen stood the greatest

transverse strain of any Australasian timber tested at the New Zealand Exhibition. Manuka is one of the best timbers in Otago for firewood, consequently there has been a great demand for it, particularly in the vicinity of Dunedin, and the supply is running short; but it is satisfactory to note that young trees grow up rapidly when the old ones are removed. This timber is well adapted for piles in situations where they are kept constantly wet, for swingletrees, spokes, and handles of tools, also for the teeth of wheels. This last is a purpose that requires wood of a particularly good quality, and although not quite so suitable as rata, manuka has been found to answer admirably. The teeth in the spur-wheels of the "*Express*" and other coasting steamers are made of manuka, and they are wearing remarkably well.

The old settlers had a high opinion of the durability of manuka, and used it extensively in fencing posts, house blocks, and similar situations of the most trying kind, but it has not proved equal to their expectations. Under ordinary circumstances manuka will decay in the ground in from six to ten years, according to the situation. The longest lived fence that I have heard of is at the Beaumont Ferry, where the posts were not decayed quite through in eleven years. This is, however, an exceptional case, as the fence was erected on dry, porous, alluvial soil, that did not retain moisture. Manuka has proved very durable in marine works; the great majority of the piles in the old Dunedin jetty, erected seventeen years ago, were of this tim-

ber, and remained quite sound till its removal recently. The George jetty at Port Chalmers, erected a year later, is in the same condition, but here the test has been more complete—all the other timbers are very much affected by the *Limnoria*, and the manuka is untouched. Professor Kirk, in 1874, reported that he had seen manuka fender piles at Port Chalmers much perforated by the *Teredo*; but the piles he refers to must have been removed since his visit, for there are no signs of the worm in the manuka piles now. The only evidence of its having attacked this timber is in the Bowen Pier, erected four years ago, where one white manuka pile has been perforated to a small extent.

No. 8. *Rata—Metrosideros lucida.* This tree grows on high ground at Catlin's River and the Longwood Ranges, but descends to sea level at the Bluff, Stewart Island, and the West Coast. It grows best on a light gravelly soil, and attains to a height of from thirty to forty feet, and an extreme diameter of about six. Logs can be obtained twenty-four feet long, and three feet diameter. The tree sometimes grows with a clear, straight stem of this height, but frequently it divides into large branches three or four feet from the ground; this kind furnishes valuable bent timbers for shipbuilding. Rata has a thin stringy bark like manuka, but larger leaves, and beautiful red flowers. The timber is the heaviest in Otago, being a little heavier than water. It is very dense and solid, with little or no sap-wood, and of a dark red colour like mahogany. Although not nearly so strong,

rata is suited for many of the purposes to which manuka is applicable, and has an additional advantage in being larger, straighter grained, and less liable to warp. Its dark colour might render it suitable for furniture, but I fear the absence of figure will be an objection. Hitherto rata has been little utilized; the construction of railway waggons at Invercargill, and the making of teeth and bushes, are almost the only purposes to which it has been applied, but the result is very satisfactory. The bearings of a water-wheel at Waikava are in good order after eighteen years' service, and the railway waggons are pronounced equal to those made from imported timber. Mr. M'Queen prefers rata to any other native wood for teeth and bushes. He says that manuka and kowhai do not wear so well—they wear off in grit or threads, whereas friction only increases the glassy hardness of rata. This timber is particularly well suited for ship timbers—natural bends of all kinds being easily obtainable. Rata is extensively used on the West Coast for firewood, and it is lamentable to see valuable trees, fit for the highest purposes of construction, destroyed in this manner.

Although this timber has not been used in situations that would test its durability, there is every reason to believe that it possesses this property to a considerable extent. I possess a sample taken from an old log on a part of the Kaihiku Ranges, where no living rata tree has existed since the settlement of the Province. It is still quite sound, and there is a large quantity in the same condition.

No. 9. Kowhai—Sophora tetraptera. This is the sole New Zealand representative of a large genus of the pea tribe, but it is intimately related to the well-known *Clianthus* of our gardens. The tree, which is of solitary habits, is found in shady, damp situations, and on light soils in all the seaboard forests. It grows to a height of about forty feet, and has a clear, straight stem about twenty-five feet long, and from eighteen inches to three feet in diameter. It seldom exceeds two feet in the vicinity of Dunedin, but from that to three feet is quite common in Southland, particularly at Forest Hill. Kowhai when young has a smooth, tough, and stringy bark, which gets coarse and brittle as the tree approaches maturity. It has beautiful drooping foliage of a feathery appearance, and yellow flowers like laburnum. Altogether the plant is one of the handsomest in our forests. It is popularly supposed that kowhai is a very slow grower, and the settlers believe that it takes twenty years to produce an axe handle, but this is an erroneous idea. So far as can be determined from the annular rings, an ordinary sized tree reaches maturity in from 150 to 200 years. It should also be noticed that the tree is easily raised from seed, and easily transplanted.

The timber is remarkably straight grained and free from knots, but it is subject to a heart-shake that impairs the strength of beams and induces splitting in piles. It is stronger than rata, but weaker than manuka. It is, however, superior to both in toughness, and warps very little. The sap-

wood, which is clearly defined, is very small; in about 200 logs, ranging from six to twenty-two inches in diameter, it never exceeded one and a half inches in thickness. The wood is of a yellow colour like laburnum, but resembles oak in grain and figure. It contains a strong resin or gum, the peculiar smell of which never leaves the timber, however well seasoned.

Kowhai is used for the same purposes as manuka and rata, together with fencing posts, house blocks, piles and similar work in a damp situation, for which it is better adapted than either. The screw shaft bearings of the "*Betsy Douglas*," and the pins and bushes of the paddle floats of the "*Coomerang*" are of kowhai, and Mr. Sparrow pronounces it equal to *lignum vitæ* for such work. Messrs. Guthrie and Larnach use this timber extensively for curved work, such as the rims for carriage wheels, the top of circular windows, and tilt frames. A good proof of its toughness and straightness of fibre is given in the teeth and bows of hay rakes. The latter are turned to the diameter of a quarter of an inch, and bent into a semicircle of nine inches without sign of giving way.

The durability of kowhai is thoroughly established. It has never been known to fail in any situation in which it has been tried. But it was scarcely necessary to make a trial, for the old trunks that have been lying in the forests from time immemorial are still as sound as when they fell. Indeed, this old timber is frequently used for fencing posts and house blocks. Kowhai has been

little used in marine works. The only instance that I know of is some bracing in the old Dunedin jetty, which was perfectly sound after being in place for seventeen years. The same remark applies to fencing and house blocks that have been in use for a much longer period.

No. 10. *Fuchsia—Fuchsia excorticata.* The fuchsia, which is the parent of many of the cultivated varieties, can scarcely be called a timber tree, but as it possesses many good qualities, and has been applied to useful purposes, it is entitled to a passing notice. The tree, which is found along the seaboard, sometimes attains a height of thirty feet, and a diameter of two feet, but it is so twisted and gnarled that it seldom yields a straight fencing post. The timber is hard, tough, and imperishable, but much given to warping and cracking. It has been used in house blocks for 20 years without showing symptoms of decay, and can scarcely be burned in an ordinary fire.

No. 11. *Broadleaf—Griselinia littoralis.* There are few trees in the bush so conspicuous, or so well known as the broadleaf, which is the sole Otago representative of its species. It is found in all the low-lying forests, but attains its maximum size on the East Coast. It grows to a height of fifty or sixty feet, and a diameter of from three to six; the bark is coarse and fibrous, and the leaves a beautiful deep green of great brilliancy. Although much larger, this tree, like the fuchsia, furnishes very little serviceable timber; it is bent and twisted, irregular outside, and hollow in the heart. The timber is

very hard and brittle, and, although crooked, is easily split. It is red in colour, and sometimes prettily marked, and not liable to crack or warp, consequently it would make furniture. Hitherto it has only been used in fencing, house blocks, and knees for boat- building. The durability of broadleaf in any situation is fully established; it has never been known to fail, and old settlers consider it the most lasting of Otago timbers.

No. 12. *Kamai—Weinmannia racemosa.* There are two trees of this species in New Zealand, but this is the only one in Otago. It belongs, however, to the same order as white mapau, whioh it resembles slightly. The properties of this timber, and its identity, have for the last year or two been the cause of considerable misconception and confusion throughout the Province. I shall therefore endeavour to describe it so as to clear up all doubts.

As will be seen by the tables of names, kamai is called black birch in the Catlin's River district and Southland, which name is given on account of a supposed resemblance to the "birches," or, more correctly, "beeches," a number of which occur in that locality. I cannot understand how such an idea could have originated, for, except in the case of the bark of one, there is not the slightest resemblance between the birches and kamai. Furthermore, the birch that is like in bark is quite unlike in foliage, and it does not grow in the same forest as kamai. Whatever be the reason, the misapplication of names is complete, for the birches are still commonly called kamai in Southland, and this has

brought the latter into disrepute, the birch with which it is most frequently confounded being very subject to decay in damp situations. Kamai is little known on the East Coast, north of the Clutha River, but is common from thence right round the South and West Coast to Martin's Bay, and particularly plentiful at Catlins River and the western districts. Like the pines, it is rare on high altitudes.

Hitherto this timber has been considered of little value by scientific and professional men; it is described as small, and inferior in strength and durability. Professor Kirk questions all its good qualities, and Dr. Hector says—"the use of this timber must be guarded against, as it is perfectly worthless." I hope to give it a much better character. Kamai is generally from fifty to seventy feet high, with a trunk from twenty to twenty-five feet long, and eighteen inches to three feet in diameter, but frequently it attains a height of from eighty to one hundred feet, and a diameter of from three to four. I am assured that trees of this size are quite common on the flat land south of Catlins River. Like most hard-woods, this tree does not grow quite straight, but the bends are not so great as to become a serious defect. The bark, which is of a light grey colour, is very thin, and adheres firmly to the trunk even when dry; the leaves are of a brownish colour, about two inches long and one inch broad, with prickly edges and a sharp stiff point. The wood, which is straight-grained, dense, and heavy, has a light brown ground colour, with grey and red figures and streaks, and very conspicuous medullary

rays. The streaks are sometimes very curious—they look like the broad strokes of a carpenter's pencil drawn at random from top to bottom of the timber, when dry they form a depression in its surface. Kamai has little or no sap-wood at any stage of its growth, so may be utilized, however small. The growing trees are very much subject to heart decay, few of the oldest ones being fit for sawing into large scantling. When sawn up green and exposed to the sun, this timber cracks and twists to a great extent. A number of logs lately in Messrs. Guthrie and Larnach's yard were almost useless through this cause. I find, however, that there is no inordinate splitting or warping in timber that has been seasoned gradually with the bark on, and the ultimate shrinkage under any circumstances is not excessive. From experiments made on thirty-eight samples I find that Kamai is about the same strength as Baltic deal, and considerably stronger than totara, Oregon pine, and kauri. Although not very flexible it gives fair warning before breaking. The bark of kamai is rich in tannic acid, consequently it is suitable for tanning leather. An analysis by Mr. Skey, of the bark of towai, a variety found in the North Island, gave thirty-one per cent. of tannic acid, which is nine per cent. richer than the bark of young oak, the best tanning material in England.

This timber is suitable for fencing posts, house blocks, railway sleepers, piles, beams, and general framing, but not for boarding or joiners' work. Being prettily marked, it might be used for turning and other small cabinet-makers' work.

The durability of kamai under the most trying circumstances, is, in my opinion, thoroughly established. Professor Kirk says that he found old specimens in the forest that were much decayed and worm-eaten, but I have never seen any in which the heart-wood was so affected, and kamai used by the settlers has never been known to fail. I have in my possession a section of a tree cut in Seaward Bush, in April, 1862, and which had lain in the forest till 1876; it is quite sound and fresh right out to the bark. I also have samples of a tramway sleeper, made from a young tree, that has been in use at the Kew Sawmills, Southland, for ten years; it is still in good preservation. Mr. A. C. Purdie kindly collected some valuable information on the subject for me at Catlins River. He found a log that had lain partly buried in the earth for thirteen years quite sound, except about a quarter of an inch of the outside sap, which was beginning to decay. He also was shown saplings that had been used in tramway sleepers for five or six years. Although thus made of immature timber, and tried in the most severe manner, they are still as fresh as when put in. On a recent visit to the West Coast I was very much gratified to find that kamai is almost exclusively used in house blocks, bridge piles, and other exposed situations, and that it has acquired a high character for durability. Many of the piles in the Greymouth wharf, and nearly all the sleepers in the Greymouth and Kumara tramway are of kamai. The tramway, for its entire length runs through or alongside a forest teeming with all kinds

of timber, consequently the choice of kamai — one of the scarcest—must be taken as a strong testimony to its suitability. Kamai piles, twelve years old, in a road bridge near Greymouth, are still in good preservation. I found that this timber was invariably called "Red Birch" on the West Coast It is known by the name of "Brown Birch" in Nelson, and as such has acquired a high reputation for durability in the most exposed situations. I could multiply similar proofs from other districts, and on undoubted authority, so I have no hesitation in giving it a high place for durability. I believe the doubts that exist on the question are due entirely to mistakes in the identity of the tree. As noticed by Professor Kirk, it is subject to the ravages of a small boring worm, but the damage done by this animal is too insignificant to be considered a defect in the works for which the timber is best adapted.

POKAKOS—ELÆOCARPUS.

The only two trees of this genus in New Zealand occur throughout the whole eastern seaboard of Otago, and are very common in the vicinity of Dunedin. So far as habitat, size of trunk, and general habits are concerned, they resemble closely the kowhai, but differ greatly from it in character of leaves and timber.

No. 13. *Pokako—Elæocarpus hookerianus.* This tree grows to a height of sixty feet, with a clear trunk of from thirty to forty feet long, and two and a half feet diameter at the base. The sap-wood is of a dirty white colour, and the heart a blotched or

marbled brown. There is, however, very little heart-wood. A tree three feet in diameter will have at least six inches of sap all round. The wood is tough and flexible and difficult to split, but not durable in a damp situation. Pokako is frequently sawn up and sold as white pine, and used for the same purposes as that timber. It has also been made into earth wagons on the Southland railways, and found to answer admirably. The heart-wood is suited for turning or light cabinet work.

No. 14. *Pokako—Elæocarpus dentatus.* This is recognized as a distinct tree from the last in the North Island, but not so in Otago. The two are found together, and are almost identical in size and appearance, but the wood is different. This one yields a much harder and more lasting timber than the other. It is also freer from sap-wood and easier split. The wood has a pinkish brown colour. Having been little used here in exposed situations we cannot speak as to the durability of pokako, but it is much prized for this property in the North, where it is known by the name of Hinau. Professor Kirk found mine props and tramway sleepers quite sound after being in use for nine years. This timber is used in Otago for much the same purpose as the preceding variety.

Ribbon Woods. Table VI. gives the name of three different trees (Nos. 15, 16, 17) that are popularly known by the name of Ribbon-wood. They are, botanically, quite distinct, but possess some properties in common, and are of little economic value, consequently I shall treat them collectively. The

trees are seldom more than eighteen inches in diameter. The wood is white or light brown, with strongly marked medullary rays, tough and easily split, but quite worthless in point of durability. One variety is so straight-grained that long rails can be split quite parallel though only an inch thick. For this reason the timber was formerly in great demand for fencing and shingles, but experience of its liability to decay has brought it into disrepute. Ribbon-wood is not durable in any situation that is in the least exposed to the action of the weather.

No. 18. *Grass Tree—Panax crassifolium*, is common everywhere throughout the Province, and well known from its unique appearance. It grows to a height of twenty-five feet, but the trunk seldom exceeds twelve inches in diameter. When young the leaves are from twelve to eigheeen inches in length, and droop against the stem, but as the tree grows old they gradually decrease to three or four inches, and become quite erect and rigid. The timber is hard, strong, and durable. The young wood being particularly tough and elastic is suitable for axe handles and similar purposes. The piles in the first jetty erected by the settlers at Port Chalmers in 1850 were of grass tree. A portion of it, still in existence, shows the timber to be in good preservation, and perfectly free from the ravages of marine animals. A piece of the piles between high and low water mark is discoloured and soft, but the fibre of the wood is still intact, and the remainder of the piles are as sound as when erected. It is worthy of remark that these piles emit a strong

offensive smell like that from a cow byre, and that cattle will not eat the leaves of any of the grass trees, which is quite in keeping with the general character of the ivy tribe to which they belong. They have all a strong smell more pungent than agreeable. Probably this may account for the fact that the piles at Port Chalmers were not molested by marine animals.

CHAPTER V.

Soft Woods.

PINES.

SO far as the constructive arts are concerned this is the most important division of the vegetable kingdom. According to Dr. Hooker and Professor Kirk, the family *Coniferæ* is represented in New Zealand by five genera and eighteen species, as follows :—

1. Dammara,	consisting	of	1	species
2. Libocedrus	„	„	2	„
3. Podocarpus	„	„	5	„
4. Dacrydium	„	„	7	„
5. Phyllocladus	„	„	3	„
Total number of species			18	

Of the above, three are mere shrubs or small Alpine trees, frequenting the mountain ranges of the

interior, generally from an altitude of 3,000 feet upwards. They are, therefore, of no economic value. The first in the list is the famous kauri, monarch of New Zealand timbers : unfortunately it is absent from Otago, consequently does not come within the scope of our inquiry, and the same remark applies to four others. This reduces the number of the *Coniferæ* timber trees in the Province to ten. I shall now consider them seriatim in the order established by Hooker, as above, which is also followed in Table VI. hereto appended.

LIBOCEDRUS.

No. 1. *Cedar—Libocedrus bidwillii.* This tree belongs to a small subdivision of the coniferæ family that has only three representatives out of New Zealand, all of which, like our native plants, frequent mountain ranges. These three are all found on the western side of the American continent, from British Columbia to the Straits of Magellan. The members of this genus were formerly classed as *Thuja* or *Arbor vitæ* ; but the present name, which means incense cedar, is now universally adopted. I do not know why they should be so named. The New Zealand varieties do not emit incense, and under any circumstance the name seems inapplicable, for the genus was not discovered until long after the practice of burning wood for incense had ceased.

"The Handbook of New Zealand Flora" gives two species of cedar—*Libocedrus doniana* and *Libocedrus bidwillii* ; the former of which is stated as

furnishing good and the latter worthless timber. In naming *L. bidwillii*, Dr. Hooker says :—" I advance this species with much hesitation. It is difficult to suppose that a timber tree described as having excellent wood, and growing at the Bay of Islands at the level of the sea (I gathered *L. doniana* on the banks of the Kawa-kawa river) should be the same as one inhabiting the mountains of the Middle Island, and described by Buchanan as having soft worthless wood, but I can find very little difference between the specimens." He further points out that they are botanically alike, and seems to depend to a great extent on the difference of the timber in making them distinct species. I hope to prove that instead of being worthless this is one of the most valuable and durable timbers in Otago, It is therefore possible that the trees in the North and South Islands are identical. Mr. Buchanan refers to the Otago cedar as *L. doniana*, and mentions no other, but Professor Kirk seems to recognise two distinct species, and calls the Otago one *L. bidwillii*. I shall therefore adhere to the latter name, but assume that the tree that I describe is the same as Buchanan's *L. doniana*.

Cedar is plentiful on the mountain ranges along the coast, but scarce in the inland forests of the Province; it is generally found from an altitude of 1,000 to 2,000 feet. The greater portion of the timber trees on Mount Cargill, and the northern slopes of Flagstaff and Mihiwaka, are of cedar. This tree is easily recognized: the trunk is usually quite free from branches, and the head is of a handsome conical

shape. The lowest branches, which are also the widest, grow in a horizontal direction, consequently the base of the cone is well defined. The trunk generally tapers more than that of any other tree in the forest. The bark is rough and fibrous like totara, but the foliage, which is erect and stiff, has a great resemblance to old rimu. The tree grows to a height of from sixty to eighty feet, with a clear trunk of from twenty to forty feet long, and two to three feet diameter, but the larger of these sizes is rare. At Mihiwaka the trunks are generally from eighteen inches to two feet in diameter, and twenty feet long, but they are somewhat longer near the head of the Waitati. I have some boards cut from a tree grown on Pine Hill, the trunk of which measured thirty-five feet in length. The cedars of the Kaihiku Ranges are the same size as at Blueskin, but some trees at Catlins River are much larger. One trunk recently measured was forty feet long, three feet six inches in diameter at the butt, and three feet at the top; the log had a slight twist in the grain, but was straight and sound throughout. Buchanan mentions a cedar, cut in the vicinity of Dunedin, that was four feet in diameter.

The wood is of a dark red colour, straight grained and solid, but rather weak. It resembles very much the famous redwood of California (*Sequoia sempervirens*), which is the timber most used in America for railway sleepers, and here for Venetian blinds. Buchanan says that the heart-wood of *L. bidwillii* is so soft that soap-bubbles may be blown through

a foot length of it; but this is no criterion of its value, for the same thing may be done with most straight-grained timbers. Blowing bubbles through new planes, which are made of solid beech wood, is a favourite experiment among carpenters in the Old Country, and I have seen bubbles blown quite easily through an oak stave three feet long that had been taken from an old beer cask. As a matter of curiosity, the experiment was tried with cedar; samples of old and young timber, seasoned and unseasoned, were tried, but in no case could bubbles be blown through three inches of heart-wood. We must therefore conclude that Mr. Buchanan's specimen was more porous than usual.

Cedar grows faster than most European timber trees; judging from the annual rings, it reaches maturity in from 170 to 400 years. There is very little sap-wood; generally not more than from an inch to an inch and a half in ordinary trees. The large one cut at Catlins River had two inches at the butt and three at the top.

This tree is very much subject to heart decay; probably a third of the aged trees in the Blueskin and Kaihiku districts are more or less affected in this way, but those on lower ground on Catlins River are nearly all sound. The decay is usually a core three or four inches in diameter, but occasionally reaching seven inches, and having similar patches throughout other parts of the trunk. This is a serious objection so far as economical cutting up is concerned, but it does not affect the durability of the timber, as the decay ceases as soon as the

tree is felled. Although a roughness of bark does not always indicate a hollow heart, it has been observed that a smooth one is a sure indication of sound timber. Cedar has been objected to as subject to excessive and irregular shrinkage and warping, but my experience of it does not warrant such a conclusion. I believe that the sound timber is as little subject to these defects as any other of the pines.

Hitherto this timber has been little used, except for fencing posts, house blocks, piles, and railway sleepers; but it is suited for ordinary house framing, and other purposes of a similar character, where great strength is not required; the straighter grained portions would make shingles, mouldings, small cabinet-work, and possibly pencils. I am assured that good samples work as freely as clear pine.

I have already referred to the low opinion entertained of this timber by leading authorities. It is further described as not durable by Dr. Hector, Mr. Buchanan, and the Jurors of the New Zealand Exhibition. I cannot understand how it could have got into such bad repute, for I can find no evidence against it; on the contrary, there is abundant proof that cedar is one of the most durable timbers in Otago — even the sap-wood lasts for years in situations where the heart of many other pines would fail. Much of the timber found on the ranges, where no tree has lived for centuries, and which is still in good preservation, is cedar. I have in my possession several samples found on the bare ranges

at Kaihiku. There is a fence of this timber at Tokomairiro twenty-two years old. Mr. James Elder Brown sent me a post in 1872, the heart-wood of which was quite fresh, and he said that the whole fence, about thirty-five chains long, was in the same condition. I have a portion of a cedar post taken in September, 1876, from a stockyard on the old Waikouaiti road, near Flagstaff, erected twenty-three years before. The heart-wood is as sound as when the tree was felled, and the sap is only decayed for a short distance at the ground level. All the posts in the enclosure are in the same condition; they average from ten to twelve inches in diameter, with about one and a half inches of sap-wood. Mr. Peter Thomson, Queen-street, has a sapling cedar four and a half inches diameter for a flagstaff; it has been eight years in the ground and is still perfectly fresh. Any other pine sapling, under the same circumstances, would be quite rotten in twelve months.

PODOCARPUS.

This section of the Coniferæ comprises about 60 species that are scattered over all parts of the world except Europe and North America. Of this number Otago possesses five, four of which are timber trees, and one an Alpine shrub.

No. 2. *Miro—Podocarpus ferruginea.* Miro is common in all the forests of Otago that lie under an altitude of 1,000 feet, and occasionally in those above that level. It is generally found associated in the same bush with red pine. The tree grows to a height of from fifty to ninety feet, with a clear

straight trunk twenty to fifty feet long, and eighteen inches to three feet in diameter, but the tallest trees are not always the thickest, particularly in dense forests.

This timber, which is far inferior to black pine in point of durability, is so like it in many respects that they are frequently confounded. I shall therefore describe their leading points of resemblance and difference. Generally black pine is a heavier timber than miro, but this is scarcely a distinction, for a full grown tree on the one hand may be compared with a young one on the other. The scales on black pine bark are thicker, and the furrows deeper than those of miro. The foliage of black pine is flat like the English yew, and of a light green colour, shiny on the lower side. That of miro is roundish and erect, and of a deep dull green, which turns to rusty red on drying. Black pine has a cluster of from four to seven small dark berries, scarcely noticeable among the foliage, while miro has a conspicuous single berry like that of the dog rose or sweet briar, almost identical therewith in size and shape, but of a redder colour. This berry has a strong odour of turpentine. Although black pine is sometimes marked in a decided manner, it has always a ground colour of clear yellowish-brown, but miro is blotched throughout, and the ground colour, which is light dirty red, varies every few inches. A horizontal section of the latter shows that the heart contains a considerable portion of dark-coloured wood, which runs in star-like points towards the circumference, hence the blotched

appearance of the timber. The figure can be varied at pleasure by simply changing the direction in which boards are cut. The annual rings and other markings in black pine are generally concentric, consequently a great variety of figures cannot be obtained. As a rule the wood of black pine is lighter and brighter in colour and easier worked than miro. The timber can also be distinguished when green by the taste and smell. These are strong and pungent in both cases, but there is a peculiarity in each easily recognised when once known. These particulars may seem too much detailed, but when we consider the disappointment and loss that have frequently resulted from the substitution of one timber for the other, their points of difference can scarcely be too well known.

Miro is a fast growing tree, and the annual rings are tolerably distinct. A stump twenty-two inches diameter on Pine Hill gave the age at 160 years. There is frequently more sap than heart in the timber, and the distinction between the two qualities is not well marked, consequently it is not suitable for exposed work, even if durable. A log from a young miro on Pine Hill, twenty feet long eighteen inches diameter at the base, and twelve inches at the top, had an average of seven and a half inches of heart. At Catlins River the smaller trees are almost three-fourths sap, but the full grown ones have only from two to four inches.

Aged miro has usually a crack in the heart, but it is small and straight, so cannot be considered a serious defect. The timber is the strongest of the

New Zealand pines, consequently is well adapted for beams in a dry well ventilated situation. As it does not shrink or warp to any inordinate extent, it is suited for ordinary house building, but being more difficult to work than red pine, the latter is preferred by carpenters. Miro is not durable in any exposed situation, except under water. It will perish in a few years if in contact with damp, and is very subject to the ravages of the large grub, which perforates the timber to the heart. I have seen bridge piles at Wallacetown a perfect mass of rottenness through the latter cause, but the portion below water level was sound to the bark. Professor Kirk reports the same state of things at the railway protective works in Bluff Harbour. The outside piles exposed to the influence of sea water were perfectly sound, but those in the embankment a few feet further in were quite rotten. He attributes the preservation of the former to the action of salt water, but the example at Wallacetown would indicate the same result in any wet situation. Twelve-inch miro piles in the George-street jetty, Port Chalmers, erected in 1860, are eaten away to about four inches by the *Limnoria*, but are otherwise in good preservation.

No. 3. *Totara — Podocarpus totara.* Totara, which is the best known and most easily recognised of our timber trees, is common in all the forests of the Province up to an altitude of 1000 feet. It is generally found mixed with black pine, but occasionally, as on Inch Clutha, forms an entire bush of

itself. The supply of totara in the vicinity of Dunedin and Invercargill is getting scarce, but there is still a considerable quantity about the Clutha mouth, and the West Coast supplies are practically untouched.

The timber seems to grow well on any ordinary soil, but prefers rich alluvial flats. Ordinary sized trees attain to a height of from sixty to eighty feet, with a clear straight trunk from twenty to fifty feet long and three to five feet in diameter; occasional trees are found up to seven and eight feet, but these dimensions, though common in the North Island, are rare in Otago. Forty stumps recently examined on Inch Clutha range from three to four feet, with a few up to five; the thick trees are generally much shorter than those of medium diameter. The bark is of a light grey colour, thick, furrowed, and stringy; it was formerly used by the natives and old settlers in covering the walls and roofs of whares and huts.

Totara is a comparatively slow grower—a tree three feet six inches in diameter is estimated to be 550 years of age. Mr. Hay, of Auckland, found young trees to grow about twelve feet six inches in ten years; when fully established, they grow two feet in a season. Totara is one of the easiest reared of our native trees. The tree has very little sapwood, but is subject to decay in the heart, like cedar; it commences on Inch Clutha when three feet six inches in diameter, and increases with the growth beyond that. The timber is of a reddish colour, like pencil cedar, but varies considerably,

according to its age and the soil in which it is grown; it is straight in the grain, easily worked, and not given to warping, but brittle, and apt to shrink if not well seasoned. Totara is suited for fencing, railway sleepers, and piles, together with architectural and engineering purposes generally, except beams, for which, on account of weakness, it is not so well adapted as many of the other timbers.

The durability of Totara under the most trying circumstances is well established and well known. I possess a piece of a log found at an elevation of about 1300 feet, on the Mount Pisa Ranges, where no tree has stood for centuries; it is as sound as when the Moa found shelter beneath its branches. I have also in my possession a survey peg from the division between Sections 1 and 2, Block X., Waihola survey district, put in by Mr. Kettle in 1848, and taken out in 1874, which is still quite fresh. All the oldest house blocks and fencing posts throughout the Province that were of heart of totara are in the same condition, so further proof of its durability is unnecessary. I should, however, remark that piles or posts made of saplings with little heart-wood will not last long in the ground. Professor Kirk, of Wellington, observed this in bridge piles, and I noticed it myself in fencing posts; the original telegraph poles on the Dunstan line also show the same thing. In black pine and old totara, where the heart-wood is solid, decay stops whenever the heart is reached; but such is not the case with totara saplings—the disease is communicated by the sap to the heart, and both perish together. Totara

in the North Island stands the marine worm better than any other native timber, but it has not shown any great resisting powers here; the piles in the Bluff wharf were perforated to the heart, and very much riddled in a few years. Experiments made by Mr. Blackett, C.E., in Wellington Harbour, show that totara was untouched after three years' immersion, whereas a piece of Tasmanian hardwood, six inches by four and a half, was eaten completely through in about half that time.

The totara of the West Coast, which is generally smaller than that of the East, is considered by Dr. Hector and Mr. Buchanan as a different tree, and Mr. A. C. Purdie informs me that there is a variety found at Catlins River not described by any of the botanists; it is of a large size, with a smooth bark, and yields very soft ornamental wood suitable for inside work.

No. 4. Black Pine—Podocarpus spicata. Like its two congeners already described, this tree frequents all the low-lying forests of Otago, but it is more plentiful on the East than the West Coast; the best supplies now available are at Catlins River and Southland.

The tree grows to a height of from fifty to ninety feet, with a trunk twenty to thirty-five feet long, and three to five feet in diameter; the latter, however, is an extreme size—four feet may be taken as the limit in ordinary cases. At Catlins River the sound trunks seldom exceed twenty-four feet in length and three feet in diameter. The appearance and properties of black pine have already been dis-

cussed in comparing it with miro, so it is only necessary to refer to the peculiarities of the former. The timber reaches maturity in about 400 years, and has about two inches of sap-wood when ripe. The tree is subject to a small heart-crack, which develops into decay when allowed to proceed, but the evil is not so great as in totara or cedar. Next to miro, this is the strongest and heaviest of the New Zealand pine-woods, and it is, without exception, the least given to warping and shrinking, and in all probability the most durable. It is suitable for all the purposes for which totara is adapted, as well as others where greater strength and solidity are required.

Miro, having been frequently substituted for black pine in exposed situations throughout the Province, has brought the latter into disrepute, and the resemblance is so great that professional men were afraid to run the risk of making a mistake. The consequence is that its good qualities are to this day little known and little appreciated. I have in my possession a portion of a fencing post cut and erected by Mr. Horman, at Makarewa, in June 1861, and taken up in October, 1876. The part most subjected to decay, that at the ground line, is perfectly sound. I have seen a black pine log, that had lain in the Waikiwi forest from time immemorial, as fresh as when it fell; it had been there so long that a fuchsia tree, nine inches in diameter, was growing across it. Mr. Buchanan found a log on Mount Cargill enfolded in the roots of three large broadleaf trees. From the size of

these trees he calculated that the log had lain about 300 years; it is still in good preservation. I possess a few inches off the end of a log that lay for twelve years in a paddock at Seaward Bush; the sap is all worm-eaten, but the heart, even to the end, is quite solid. Mr. M'Arthur sent me, in 1872, a piece of a post that had been ten years in the ground at Waikiwi; the edges at the surface of the ground were almost as sharp as when split, and there were many more in that locality in the same condition. I have already referred to the sapling telegraph posts. Those of birch and totara were rotten through in twelve months, but the heart of the black pine ones, although very small, stood for five or six years; indeed, it was not decayed when the posts were removed to be replaced by iron ones. Black pine, however, does not stand the ravages of the marine worm as well as totara. The retaining wall at Rattray-street, erected in 1867 and removed in 1875, had been attacked, though situated so far from the open ocean.

Black pine and totara contain a resinous matter that resists the adhesion of paint when the timber is green. This property, which builders consider a serious objection, is, in reality, a great recommendation, for it promotes seasoning.

I have in this paper adhered to the popular name of black pine for this timber, but the native name matai, which is always used in the North, is becoming common in Otago also. I trust it will soon completely supersede the former.

No. 5. *White Pine—Podocarpus dacrydioides.*

Although more gregarious than the other pines, this tree is found associated with its congeners in all the sub-alpine forests of Otago. It grows freest in low swampy ground, but the best timber is produced on moderately dry soil.

White pine grows to a height of from 120 to 150 feet, with a trunk up to seventy feet long, and five feet in diameter at the base. One log lately examined on the Orepuki railway measured fifty-five feet in length, five feet in diameter at the butt, with three feet of solid heart-wood, and three feet in diameter at the top, with one foot of heart. At Catlins River the average dimensions of trunk is forty feet long, and from two feet six inches to four feet in diameter, the largest trees having about two feet of heart. As a rule there is seldom more than two or three inches of heartwood in trees under three feet in diameter, and the difference between heart and sap-wood is in all cases very indistinct. The shape of the tree, colour of bark, and appearance generally are somewhat like black pine. Still there is little difficulty in distinguishing them when growing, and the difference in the wood is greater than between any other two of the pines. In consequence of the evenness of the colour, and the closeness of the annual rings, it is difficult to estimate the age of white pine. Ordinary-sized trees probably reach maturity in from 370 to 600 years. Young trees are easily transplanted and cultivated. They shoot about eighteen inches per annum. Old trees have a slight heart crack, but it is too small to be considered a defect.

The sap-wood of white pine is of a dull white colour, and the heart-wood of a pale yellow or straw colour. It was the weakest and lightest of the native building timbers tested at the New Zealand Exhibition; but my experiments, hereinafter referred to, show it to be stronger than totara and kauri. Its strength is considerably greater than that of European red deal and English elm, and its weight is much the same as the former. The wood is straight-grained, soft, flexible, and not given to warping or excessive shrinkage, consequently it is well adapted for flooring, weather-boards, and the other ordinary joiners'-work for which white deal is usually employed. Tradesmen will not allow a comparison to be made between the native and imported articles. They say the latter is infinitely superior, and that white pine is too soft and spongy for anything like good work. I do not think there are sufficient grounds for such a conclusion, which is in all probability arrived at by comparing seasoned foreign timber, the only kind that can be got here, with green colonial timber, the only kind that is used. The white pine timber of New Zealand is in my opinion equal, if not superior, to Baltic white deal for all the purposes for which the latter is adapted, and its supposed inferiority is due entirely to defective seasoning.

White pine is not durable in any situation where exposed to damp or frequent changes from wet to dry. It will not last two years in fencing posts or house blocks; even rails and beams of bridges that are clear of the ground decay in three or four years,

the least moisture retained in a joint or mortice induces rapid destruction. The heart-wood is durable, but there is so little of it, and there is so much danger of using sap instead, that no advantage can be taken of its good qualities. I have a piece of white pine heart-wood taken from a large log that has been felled many years at Deborah Bay. It is still in good preservation. Some of the piles in the George-street jetty, Port Chalmers, are of white pine. They are eaten away to a third of their original diameter by the *Limnoria*, but the timber has not suffered much from natural decay. Although soft and weak, the fibre is still intact. Professor Kirk says that white pine in Wellington and other places in the North is subject to the attack of a minute double-winged insect, but so far as I can ascertain it has no such enemy in Dunedin.

This timber is known in all the Provinces except Otago by the native name of "kahikatea." I think we should adopt it also, not only on account of being more euphonious, but for the reason that so many timbers in other parts of the world are called white pine.

DACRYDIUM.

Otago possesses five members of this genus, which is a small one confined to the Southern Pacific; they consist of four timber trees, and a mountain shrub. According to Gordon's "Pinetum," there are only two large timber trees of this family out of New Zealand; one frequents the mountains of Sumatra, and the other is the famous Huon pine of Tasmania.

No. 6. Red Pine — Dacrydium cupressimum. This is the most plentiful of the pines, and the most used timber tree in Otago; it is found in all the low-lying forests round the coast from Waikouaiti to Martin's Bay. It grows to a height of one hundred and fifty feet, with a clear straight trunk up to eighty feet high and five feet diameter. A log recently taken at random on the Orepuki Railway, measured fifty-five feet to the lowest branch; it was four feet three inches diameter at the butt, three feet six inches diameter at a height of forty feet from the ground, and four feet three inches diameter at the top. At Catlins River mature trees measure about forty feet long by two feet six inches to four feet diameter; those from sixty to eighty feet, of which there are a large number, do not generally exceed eighteen inches in diameter. The logs that come from Pine Hill are usually about twenty feet long, and from eighteen inches to two feet six inches thick. Red pine trunks have little taper, they are almost cylindrical from the ground to the lowest branches; the base is usually furnished with buttresses that run eight or ten feet up, consequently the trunk is not round for that distance. The bark is rough and scaly, and of a dark brown colour; it comes off in large flakes every year, which in course of time forms a huge mound of a peaty nature round the tree. This mound ignites readily when dry, so is possibly the cause of many bush fires.

Young red pine is noted for its beautiful green foliage, which droops in feathery tassels like larch

or willow; but, as the tree grows old, the foliage becomes stiff and erect like the other native pines. An ordinary-sized tree reaches maturity in about 500 years, and young plants make wood at the rate of about a foot per annum. Seedlings are very tender and difficult to rear when removed from their native forests, and large trees are easily killed by stripping a ring of bark near the roots. The bark of the red pine is good for tanning, and the juice of the young branches was made into beer by Captain Cook; but I have not heard of its being utilized in the same way by any other white man.

This timber has a very large proportion of sap-wood which is not well defined. There is little or no heart in trees under eighteen inches in diameter, a size that is frequently cut into market stuff. The following notes give the quantity of sap-wood in a number of large trees at Orepuki:—

No. 1.—4′ 6″	diameter,	8	ft. from ground,	had	10	in. of sap.
2.—4′ 0″	„	10	„	„	4½	„
3.—3′ 7″	„	40	„	„	4½	„
4.—3′ 6″	„	20	„	„	6	„
5.—3′ 0″	„	40	„	„	4	„
6.—2′ 8″	„	9	„	„	4	„

The trunk of No. 1 was forty-six feet long. Three-feet logs from Pine Hill, Water of Leith, and Blanket Bay, examined at Messrs. Asher and Co.'s yard, showed from three to four inches of sap. One tree nineteen inches in diameter had only nine inches of heart. At Catlins River, where this tree seems to grow remarkably well, the proportion of sap-wood is smaller than near Dunedin; three-feet trees have only about

three inches of sap, which is tolerably well defined, and the heart shows at an earlier stage of growth.

Red pine frequently grows with a twist in the trunk, and more sap-wood on the one side than on the other, consequently the timber is cross-grained and irregular in strength and consistency; mature trees are also subject to heart shakes and cracks. This defect is occasionally a want of cohesion between the annual rings in the inner core of three or four inches, but oftener it consists of a straight crack from three to nine inches long, filled with gum or resin. This opening is of little moment in straight logs, but it renders the whole centre unserviceable for sawing up when the timber is twisted. The state of the bark is a good indication of the ripeness of red pine; trees in vigorous growth have large dark-coloured scales that adhere closely at certain seasons, and those of mature age have short light-coloured scales, easily removed at any season of the year.

The colour of red pine timber is very variable; it ranges from light yellow to deep red, and there is generally a handsome figure in boards. It is the third in order of strength of our Otago pines, but is more irregular in grain than black pine or miro, consequently is less trustworthy in beams. Red pine is much used in house framing and general carpenter-work, for which it is well adapted; but on account of being harder and more brittle, and more given to shrink irregularly, it is not equal to white pine for flooring, weather-boards, and internal joiner-work. Red pine is much prized as a furni-

ture wood, some of its figures being remarkably beautiful. When well fitted and seasoned, it stands as well as most foreign timbers that are used for this purpose. I believe it would command a ready sale as a furniture wood in the English markets if properly introduced.

The heart of red pine is durable; any quantity can be got in the forest quite fresh after lying for ages, but in consequence of its small size, and the danger of using sap instead, we must treat the whole tree as perishable. The ordinary red pine of the market is very liable to decay in any exposed situation. A survey peg which I put into the ground at Tokomairiro in August, 1869, was quite rotten in April, 1872. Beams eighteen inches by fifteen, put into the Southland railway bridges in 1863, were a mass of putrefaction in 1868; nothing but a crust about half an inch thick remained solid, and this was in the most favourable situation possible, for there was no planking on the bridges, and no mortice holes or checks on the upper side of the beams. Although not nearly so bad, a similar state of things was observed in the old Bell Tower, Dunedin, erected in 1864, and pulled down in 1872; some of the timbers were fresh in the middle, but all were rotten at the joints.

Rimu, the native name of this tree, is now tolerably well known in Otago. So if professional men and timber merchants would only encourage its use, it would soon supersede the vague conventional term of red pine.

Mr. Henry Gordon, C.E., Greymouth, from whom

I have received much valuable information on the West Coast timbers, says of red pine:—

"There are two varieties of this timber here; one has a white and the other a red heart. To look at the two trees when growing I cannot make any distinction, still the timber is quite different; in some of the white hearted rimu the timber is very dense, and when sawn there are streaks in it that resemble bone; but although this description of rimu appears to be of a lasting character, I have not seen any of it used for a sufficient length of time to test its durability. The other description of rimu, with the red heart, I believe to be very durable timber but it is so hard to get, that other portions of the tree require to be used along with the heart, thus causing the timber to have a bad name. There is a peculiarity about rimu which I have not observed in any other timber—that is, the amount of heart-wood there is in different trees; in some instances there will not be more than two inches of sap-wood at the butt of the tree, and the remainder all red heart; twelve feet higher up the tree the red heart will be redneed to one-half the diameter, and in the next twelve feet the heart entirely disappears. In other trees the red heart will continue to the top of the tree. In some trees there is an open spongy wood between the sap-wood and the heart-timber, which, in a great many instances, is taken for heart-timber, but is in reality totally worthless, and will rot quicker than the sap-wood. Timber of this description can easily be detected, if cut into boards and planks and used in flumes. On a warm day, when the water is flowing in the flume, the outside of the boards will be quite dry unless some of this timber is used, and if so, the outside of the board will be wet, and have a dark appearance. I have had a deal of trouble to prevent timber of this description from being used when the specification only mentioned the sap-wood, which is quite distinct from the porous wood referred to. The sap-wood in rimu can never be mistaken; it varies in thickness from two to four inches, and in some instances I have seen six inches of sap-wood; it has a dirty white appearance, with straight streaks a little lighter than the other portions, and has a glossy appearance, resembling kahikatea coloured with kerosene oil.

"When nothing but the red heart of rimu is used it will last a considerable time. In a bridge over the Stillwater Creek, on the Greymouth and Reefton road, after standing for seven years, the chords, which were of red heart of rimu, were as sound as when the bridge was built."

No. 7. Yellow Pine—Dacrydium colensoi. This tree is only found in small quantities on Pine Hill, Mount Cargill, and other East Coast ranges, but is tolerably plentiful on the West Coast.

It is a small tree seldom exceeding forty feet in height, with a trunk twenty feet long and two feet six inches in diameter. It is remarkable in frequently having two distinct kinds of foliage on the same tree, that on the lower branches being flat and pendulous, and on the top ones round, rigid, and erect. The bark is like that of young red pine, but the timber is quite different. It is of a clear yellowish colour, with little sap, straight in the grain, dense in texture, and solid throughout; altogether one of finest looking of our Otago pinewoods.

The tree contains a large quantity of resinous matter, which cannot be expelled by artificial drying with hot air. It burns freely, emitting a dark bituminous smoke, and a strong smell exactly like the knots of larch. Some Scandinavians, near Mount Cargill, attempted to extract pitch from the yellow pine, but I do not know whether they succeeded. It is from this resinous property in the timber that the settlers' name of tar-wood is derived.

Yellow pine is employed in the North Island for ordinary building purposes, but on account of being scarce and of a small size it is little known in Otago

as a timber tree. The durability of the wood is undoubted. Three-inch saplings used as piles in a Maori pah at Waimate, are still as fresh as when driven eighty years ago. This wood seems admirably adapted for turning and other work of a similar kind where evenness of grain and density are the desiderata.

No. 8. *Westland Pine—Dacrydium Westlandicum;* and *No.* 9. *Silver Pine—Dacrydium intermedium,* are two new species lately determined as such by Professor Kirk, who gives a minute description of them in Vol. 10 of the Transactions of the New Zealand Institute.

Captain Campell-Walker, in his Forest Report, refers to these timbers in the following terms:—

"Westland Pine, silver pine, or white silver pine—*Dacrydium Westlandicum*, N.S.—is a handsome tree, which has hitherto been confused with white pine by botanists, but in reality belongs to a different genus. So far as known it is restricted to the western portion of Nelson and Westland. It is a handsome tree thirty to fifty feet high; trunk, one and a half to two and a half feet in diameter, with white thin bark and minute closely imbricating mature leaves. The young leaves are terete and spreading; gradually become shorter and somewhat flattened, resembling the young leaves of white pine before they pass into the appressed condition. The timber is hard, dense, and extremely durable; it is used for general building purposes, piles, bridges, and wharves, and realises a higher price in the market than red pine. It has been exported in bulk to Melbourne, where it is in demand. In altitude it ranges from the sea level to nearly 2000 feet, and was observed at intervals from Greymouth to Okarito; in all probability it will be found along the whole of the whole of the West Coast as far south as Dusky Bay.

"Yellow Silver Pine—*Dacrydium intermedium*, N.S. This species somewhat resembles the preceding, but has larger mature

leaves, less closely imbricating; the young leaves also are larger, and resemble those of red pine; the branches are shorter, with dark bark, which is much thicker than the preceding. It not unfreqently branches from near the base. The timber is yellowish, dense, and heavy; it is even more durable than *D. Westlandicum.* It has a wider range than that species, being found in the North Island, but does not descend to the lowest levels."

Mr. Gordon, C.E., adverting to my original Papers on Timbers, and to the two species now under consideration, writes me as follows :—

"Silver Pine. I take this to be the same as yellow pine-- *Dacrydium colensoi.* The character of the timber answers exactly the description you give of yellow pine, with this difference, that it is not remarkably dense in texture: its specific gravity when green is less than kahikatea—*Podocarpus dacrydioides.* On some parts of the West Coast it is known by the name of Huon Pine; but it is possible that what you term yellow pine is what we term here mountain pine. It is extremely dense in texture, and its specific gravity is about the same as matai. I am informed that mountain pine is very durable, but I have not seen it in use sufficiently long to speak of its merits. The bark resembles silver pine, but not more than three-sixteenths of an inch in thickness.

"However, I shall describe what is termed here silver pine as near as possible. The trees are seldom more than two feet in diameter, and forty feet in height. The bark resembles the bark of kahikatea—*podocarpus dacrydioides*—only it has a light glossy appearance, which the other lacks; it is from a quarter to half an inch in thickness. The sap-wood is about two and a half inches thick; and this timber, unlike its congeners (which rot in the heart first), commences to decay from the outside to the heart. There are many instances of two different descriptions of foliage on the same tree, totally unlike each other. One of the descriptions of foliage resembles the foliage of the kahikatea, without the small prickly leaf resembling a round plaited thong or cord. The other description of foliage has a stiff erect leaf, shaped like the foliage of totara, only much smaller.

The heart-timber is of a bright yellow, close grained, but very brittle; it is well adapted for piles, but will not bear a great transverse strain. I think there is little doubt as to its durability. In the bush between Okarito and Gillespie's Beach there are large logs lying on the ground, and the roots of other timbers (large trees) grown over them, and in no instance have I ever found this timber decayed beyond the sap-wood, which rots from the outside; even in saplings the heart, be it ever so small remains sound. It might be as well to state that there is a large amount of resinous matter in the timber, which makes it easily to burn; but it is dangerous to use it as firewood in a house, as it sparkles and flys a considerable distance from the fire."

No. 10. *Celery Pine—Phyllocladus alpina.* The genus to which the celery pine belongs only embraces three timber trees, one each in Borneo, Tasmania, and New Zealand. One specimen is common in the Northern Provinces, and at high altitudes on the West Coast, but rare on the East Coast of Otago. There are, however, a few trees to be met with in the vicinity of Dunedin, and from the Clutha southwards.

The tree grows to height of from fifty to sixty feet, with a straight clear trunk two or three feet in diameter for two-thirds of the distance. It is a remarkably handsome plant of the true pine shape. The leaves are quite different from the other conifers of Otago: instead of a mere cluster of thin foliage, the tree is covered with large well-defined leaves like the common celery plant, from which the name is derived, but of a brownish colour. The bark is smooth and solid, dark on the surface, and of a uniformly brown colour inside. It is known to be good for tanning, and the natives use it as a dye. The wood is soft, straight grained, tough and

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flexible, with little sap, but subject to heart decay. The colour is somewhat like miro, without the irregular blotches.

This timber has not to my knowledge been used in Otago. It is suited to any and all of the purposes to which the other pines are applied. According to Professor Kirk its durability is undoubted. He gives it as high, if not a higher place than totara.

With the exception of the botanical name, which has been altered from "*P. trichomanoides*" to "*P. alpina*," the above remarks are exactly as they appeared in the original paper. In his description of *P. trichomanoides* in Vol. X. of the Transactions of the New Zealand Institute, Professor Kirk says—

"In his account of the building timbers of Otago, Mr. Blair states that this species is common 'at high altitudes on the West Coast but rare on the East Coast of Otago,' and that 'it grows to a height of from fifty to sixty feet, with a straight clear trunk two to three feet in diameter for two-thirds of the distance.' He adds, 'A few trees are to be met with in the vicinity of Dunedin,' &c. Unless Mr. Blair has been led astray by the native name Tanekaha being misapplied to *P. Alpina*, it is difficult to account for this error, as the present species does not occur in Otago, and *P. Alpina*, although plentiful in the district mentioned by him, is usually little more than a bushy shrub, and never attains dimensions at all approaching those of *P. trichomanoides*."

Professor Kirk having shewn me the leaves of *P. trichomanoides*, which are quite distinct from the leaves of the Otago plant, it is clear that I was mistaken in the botanical name of the latter, and the dimensions of the tree are considerably over-stated, but the other particulars are substantially correct. I have now in my possession boards

taken from a log eighteen inches in diameter, and I find that the timber is frequently utilised in Southland, where it is known by the name of "New Zealand Hickory."

Writing to me about celery pine, under the name of "Tanekaka," Mr. Gordon says:—

"I have seldom seen trees of this description more than eighteen inches at the base, and about forty feet in height. The timber has an extremely resinous smell, and burns very freely when green. At Okarito, I saw it used in trestles of fluming; but it became totally rotten in about five years. It may, under some conditions. be durable timber, but saplings of eight and ten inches in diameter decay very fast. A good deal of this timber was used in tunnelling on the Kaneri Water Race, and I am informed that wherever it was used it shows to be of a perishable nature. This may be accounted for in this wise—that the timber used here have all been small trees, and principally sap-wood; although, as a rule, the sap in small trees does not exceed one and a half inches or two inches thick. The bark on an ordinary sized tree is about three-sixteenths of an inch in thickness."

CHAPTER VI.

SOFT WOODS—CONTINUED.

BIRCHES.

THE next most important class of soft woods is the birches, or, more correctly, beeches. They are, botanically, true beeches, consequently would be classed with the hard-woods in England, but as the majority

of the New Zealand trees yield very soft timber, I have kept them with the soft woods. The birches are the most plentiful of the Otago timber trees, and at the same time the least known, consequently they require careful consideration at our hands. They belong to the genus *Fagus,* which has one representative in Great Britain, the common beech, and a few more in other temperate countries. This genus in turn belongs to the same botanical order as chestnut, oak, hazel, and hornbeam. The New Zealand beech has almost an exact counterpart in South America. Darwin's description of the forests in Terra del Fuego is, in every respect, applicable to those of the West Coast of the Middle Island.

As already stated, the birches occupy almost exclusively the forests of the interior, and are abundant on the West Coast, but rare on the East. There are no large trees in the vicinity of Dunedin, but they occur with more or less frequency in all the seaboard forests south of the Taieri. During a recent exploration of the passes in the main range I observed that invariably the western slope was covered with red birch *(Fagus fusca)* ; the eastern slope with black-heart birch (*F. solandri*) ; and the summit with silver birch (*F. menziesii*). Taken in connection with the fact that the foliage and some other parts of silver birch partake of the characteristics of the others, this circumstance seems to indicate a regular gradation in the species.

As will be seen by the tables, the utmost confusion prevails among the common names of the birches. There are scarcely two districts, a few

miles apart, in which the same name is applied to the same tree, and a similar result may be obtained by consulting two bushmen in the same bush. With the view of obviating this difficulty Professor Kirk suggested "the adoption of new names based on the obvious characteristics of their foliage; for *Fagus fusca*, tooth-leaved beech; for *Fagus solandri*, entire-leaved beech; and for *Fagus menziesii*, round-leaved beech." On first sight I thought this an excellent arrangement, and did what I could to establish it, but a fuller acquaintance with the trees convinced me that it was unsuitable. The difference between the leaves in many localities is too small to be noticeable by anyone but a scientific expert, and under any circumstance the peculiarity that is relied on for identification is not always the leading feature in the leaf. For instance, the teeth in some of the leaves of *F. fusca*, from Lake Wakatipu, are so small that they are only seen on close inspection. Indeed, they might easily be confounded with the leaves of *F. solandri*, from the Five Rivers Plain, which are nearly as large. The latter are entire, but have a curious horizontal corrugation in the margin that gives them the appearance of being toothed. The leaves of *F. menziesii*, although round, are not always so conspicuously round as some leaves of *F. solandri*, and the nicks in the former are in many cases so like the teeth of *F. fusca* that they cannot be distinguished by popular eyes. From this it will be seen that the names of the birches are still in an unsatisfactory state. Failing good native names, of

which there are none that I know of, I would suggest the retention of the most common Otago names, which seem to be based on the appearance of the wood and the tree itself:—For *Fagus fusca*, red birch; for *Fagus solandri*, black-heart birch; and for *Fagus menziesii*, silver birch. The red birch timber is invariably red; black-heart birch is often white, but it has always black marks, and the heart is generally all black; the trunk is also frequently covered with a jet-black moss. Silver birch has, when young, a silvery bark like the English birch, and the wood, although sometimes of a reddish colour, has generally a silvery tinge, and always a silvery grain. It might be advisable to change to the correct botanical name of beech, as suggested by Professor Kirk, but the other is so well established throughout the Colony that there would be some difficulty in doing so, and as some of the trees are very like the Old Country birches, the name is tolerably appropriate.

No. 11. *Silver Birch — Fagus menziesii.* This species is the most common on the East Coast. It exists with the other two in the inland forests, and, according to Dr. Haast, it is the only one between Wanaka and the West Coast.

It is a tall slender tree, frequently eighty feet long in the trunk, but seldom exceeding three feet diameter at the base; the average diameter at Catlins River, Tuapeka Mouth, and the Blue Mountains, is about two feet. I saw a few trees in the Buller Valley five feet diameter. The stem is straight and cylindrical, and free from branches, and the top

is round and compact, so the whole plant has a remarkably handsome appearance. Mr. Buchanan says that *F. menziesii* sometimes attains a diameter of twelve feet; but this and other remarks on the timber leads me to believe that he refers to *F. fusca.* The bark in young and middle-aged trees is very thin, seldom exceeding a quarter of an inch; the colour is silver-grey, with numerous horizontal markings like cherry, hazel, and the English birch; the outer layer also peels off as in those trees. When the silver birch reaches maturity, or is allowed to stand beyond that stage, the bark gets dark and rough, and the horizontal markings disappear; but its ultimate thickness seldom exceeds half an inch, and it is never cut up into deep close vertical furrows like the bark of red birch. The leaf is from a quarter to five-eighths of an inch in length, rather thick and stiff, but without external ribs or veins; the margin is cut into by a small double notch with straight edges. The tree reaches maturity in from 150 to 300 years, and grows freely under cultivation; young plants shoot about a foot per annum. The silver birch is so tenacious of life that the removal of a ring of bark does not kill large trees.

The growing timber is remarkably free from heart-shakes and other defects of a similar kind. Trees that have stood long after reaching maturity occasionally show a small core of decayed wood in the centre; but it is so small, and occurs so seldom, that it can scarcely be called a defect.

It is difficult to determine the proportion of sap-

wood in silver birch; young trees are of a uniform colour and texture from the pith to the bark, and the wood gets gradually darker and harder towards the centre in old trees, so that a sharp line of distinction between heart and sap cannot be struck; perhaps three and a half inches of sap-wood on a two feet tree will be a fair average. The colour of young timber is a pinkish-white, with occasional reddish streaks and knot-like spots. The heart in old trees is deep pink or light red, verging towards the outside into the same tints as the young wood; both kinds have a peculiar silvery lustre—this is easily recognised when once known. The wood of silver birch is even grained, soft, flexible, and tough, and not given to excessive shrinkage or warping;—perhaps there is no other timber in New Zealand so suitable for internal joiner-work and mouldings; it is also admirably adapted for tubs and other light coopers' work, and should answer for making patterns. Altogether, this is one of the most useful soft woods in Otago.

Silver birch timber is not durable in any situation where exposed to damp, or alternations from wet to dry; in this respect it is about on a par with white pine. I have in my possession a section of a tree rotten quite through after lying felled for four years in the West Taieri Bush, and a similar result was obtained under the same conditions in twelve months on Inch Clutha; further, a tree that had been cut, but left leaning against another, was completely worm-eaten in that time. I have had similar evidence from the Blue Mountains, and we have negative

proof in the absence of old trunks in the forest; so silver birch must be set down as a perishable timber.

No. 12. *Red Birch—Fagus fusca.* With the single exception of kauri, this is the largest member of the vegetable kingdom in New Zealand. It is the chief occupant of the interior and West Coast forests of Otago, and occasionally descends in small patches and individual trees to sea level on the East Coast. It affects light soil on shingly plains or the mountain side, and grows in open bush with little undergrowth. The roots rarely penetrate more than three feet into the ground, and the base of the trunk in large trees is frequently supported by buttresses four or five feet high. The other two kinds of birches generally occur in the same forest, which seldom contains any other timber in large quantities. Mr. M'Arthur estimates that 80 per cent. of the trees in the Burrwood forest are red birch, and much the same proportion exists on the West Coast.

The trees grow to a height of from eighty to one hundred feet, with a trunk, free of large branches, fifty to eighty feet long, and three to eight feet diameter; occasionally, howerer, it attains the enormous diameter of ten to twelve feet at the base. Mr. Surveyor Innes states that the Wakatipu red birches range from three to four feet six inches, but he has seen them at Te Anau from seven to nine; and six to eight feet trees are frequently met with on the Five Rivers Plain. The Burrwood Forest timber is about the same size as that at Lake Wakatipu, but the few trees on Inch

Clutha are much smaller; the trunks average from twenty to thirty feet long, and two to three feet in diameter. Two red birch logs from the Blue Mountains, measured at the Inch Clutha Bridge, were respectively thirty-five feet long by two feet four inches in diameter, and thirty-eight feet long by two feet in diameter; they were both quite cylindrical, straight, and sound throughout. The trees in a small patch of bush at West Taieri average about four feet diameter.

The bark of young red birch is somewhat like that of mature silver birch, but on old trees it is from half an inch to an inch and a quarter thick, of a dark reddish-brown colour, very rough on the surface, and cut up into deep vertical furrows as close as they can lie. The leaf is of an oval shape, from three-eighths of an inch to an inch and a half long, very thin and flexible but provided with projecting ribs or veins. The edge is serrated at regular intervals with generally a curved indentation, but they vary very much. Dr. Hooker says that Mr. Travers sent him leaves of *F. fusca* that were quite entire, and I have seen specimens from Lake Wakatipu in which the teeth were only noticeable on close inspection. The smaller leaves of red birch can scarcely be distinguished from the large ones of silver birch, but the whole foliage of the former is more open, spreading, and pendulous than that of the latter. Although there is sometimes very little difference in the leaves, and even in the appearance of the wood of *F. fusca* and *F. menziesii*, there is always a great difference in the

quality of the wood. Professor Kirk, a short time since, kindly identified a number of specimens for me; I could see very little difference in some that he had referred to as separate species, but the correctness of his classification was afterwards verified in a very remarkable manner: two trees were found in the West Taieri Bush that had been felled on the same day four years ago—one was rotten and the other quite sound. Their foliage, which still remains intact, is to the casual observer the same, but on comparing them with Professor Kirk's specimens, the rotten tree is found to be *F. menziesii*, and the sound one *F. fusca*, a result entirely in keeping with the respective characters of the timbers.

Red birch, like its congeners already described, grows freely under cultivation, and reproduces itself rapidly in its native forest. In Westland I have seen a regular thicket of young plants growing on a dry shingle bank thrown up in making a water race; further, they grew luxuriantly in the interstices between two logs forming a foot-bridge over a stream. A red birch tree four feet diameter is estimated to be from 300 to 350 years of age. The timber is free from twists or bends, but is subject to heart decay, like cedar and totara. All the larger trees that have passed maturity are more or less affected in this way.

This timber is generally of a uniformly reddish colour throughout, with little or no figuring or markings. It is straight grained and splits freely, but not nearly so smooth as silver birch. The sap-

wood is of a dirty yellow colour, and well-defined; it ranges in thickness from two to three inches in four feet trees, but those grown on swampy land have much more. Red birch is the strongest of native soft woods tested at the New Zealand Exhibition, but my experiments give it a much lower value. It has, however, a great advantage over many other of the Otago timbers that stand heavier strains in being so uniformly straight grained and fibrous as to give good warning before breaking; indeed, the samples tested by me seldom broke right through. Like its near relation, English oak, this timber shrinks very much in seasoning, as will be seen by Table VII. I found boards to contract as much as one-tenth of their width. This shows the absolute necessity of having the timber thoroughly well seasoned, but it is otherwise no serious defect, for, notwithstanding the excessive shrinkage, there was little warping in the boards.

On account of its combined strength and toughness, red birch is perhaps better adapted for beams and general framing than any other Otago soft wood, and it is equal to all except white pine and silver birch for general joiner-work. In reporting to the University Council in 1875 on the subject, I said that red birch was "not suitable for internal furnishing of houses." This opinion was based on the idea that it became very hard with age. I now find that such is not the case. The hard samples turned out to be kamai, and a number of old red birch specimens since obtained are all tolerably soft.

and flexible. In addition to the uses just mentioned, this timber is suitable for piles, sleepers, and other engineering purposes. In short, it is more capable of universal adaptation than any other Otago timber.

Our experience in Otago of the durability of red birch is comparatively limited. It has hitherto been little used, except as fencing in Upper Southland, and for building purposes in the Wakatipu district, but its lasting qualities have been fully tested and universally acknowledged in the Northern Provinces. The well-known Waiau-ua bridge, erected by Mr. Blackett, in Nelson, thirteen years ago, entirely of this timber, is still perfectly sound, and fencing posts in Wellington are in the same condition after fifteen years' use. Mr. Cameron, of the Dome Station, in Southland, informs me that he has seen red birch posts quite sound after standing for fourteen years in the ground; and twenty miles of fencing erected by him on the Five Rivers Station, in 1867-8, is still in good preservation. I also possess the following examples as proofs of the durability of red birch. :—

1st. Piece of split timber that has lain in the West Taieri Bush for ten years.

2nd. Portion of fencing post, eight years in the ground, at Tuapeka Mouth, and

3rd. Section of tree that had been felled in the West Taieri Bush for four years.

All of which are still quite sound and fresh.

The red birch on the West Coast is reported on by Mr. Gordon in the following terms :—

"*Towai—Fagus fusca.* This is the most useful timber on the West Coast for bridge building, or for any purpose where great strength and durability is required. The trees grow to a height varying from 70 to 110 feet, having a diameter at the base, in some instances, of 10 feet, but the most useful trees are from two to four feet in diameter, the larger ones being generally hollow or decayed in the centre. The amount of sap-wood varies in different trees, but I think the average may fairly be set down at about two inches. This timber is liable to heart cracks, and has a great tendency to spring from the centre outwards. In many instances I have observed trees of three feet in diameter split from one end to another as soon as a commencement was made to rip them with a pit saw. The sawyers generally use the precaution of clasping them with iron dogs to prevent this from taking place. There is one peculiarity in *fusca* which makes it objectionable to use in round logs, and that is, the timber is very faulty. It is quite a common occurrence to get a tree 50 feet long in the barrel without a branch, and to all outward appearance quite sound, and it may be so at both ends, and still decayed here and there in patches varying from a foot to six feet in length in different places. The decayed parts are not generally soft and spongy but equally as hard as the sound timber; only, instead of having a light reddish-brown colour, it has a black mottled appearance. I have found it necessary in using round logs in building piers for bridges to bore small holes here and there to test the timber, and afterwards to plug the holes up with plugs steeped in tar. I had a deal of trouble in getting sound timber for the cords of the bridges on the Nelson Creek Water Race, where long lengths were required, which in some instances were 66 feet. These were generally squared out of logs of about two feet in diameter. Sometimes the three sides would appear perfectly sound and the fourth one decayed in several places and unfit to be used. There was an objection to have them sawn, unless out of very large logs, as the long lengths generally warp more when sawn, the nature of the timber being to shrink more on the outside of the log than in the centre. When this timber is sawn into scantling and planks, great care must be taken to prevent it from being fully exposed to the sun, or it will twist and warp so that it is unfit for use. Although this

timber is straight in the grain and splits easily, still it will not split into rails for fencing, or slabs, unless off the quarter, which makes the slabs and fencing rails always feather-edged.

I have not had sufficient experience of *fusca* to speak personally of its great durability, but I have seen it taken out of the ground, where it had been used for mining purposes for nine years, quite sound, and a few days ago I examined the bridge across the Arnold River, on the Greymouth and Reefton road, which is built entirely of this timber and matai, (*Podocarpus spicata*) and is five and a half years old. The top planking was being taken up with the view of replacing it with new timber, and in every instance the planks of the *fusca* were quite sound, while the matai planks were decayed. Even where the iron spikes went through the *fusca* planks, the sides and edges of the holes were quite sound, and the top of the chords, under the planking, (which is generally the first place to show signs of decay) was as fresh as when the bridge was built. From what personal experience I have had, and from information obtained from different sources, I have great faith in the durability of *fusca*.

When the trees are young (saplings) they have a smooth bark of a light grey colour, but until the trees are old enough to have rough bark, they are not fit to be used. In any stage of the tree the surface under the bark is always corrugated vertically. The thickness of the bark in full grown trees ranges from three-quarters of an inch to an inch and a quarter.

No. 13. *Black Heart Birch—Fagus solandri and F. cliffortioides.* Dr. Hooker says that although very similar, these plants are distinct species, but the only difference he makes is in the shape of the leaf. We may therefore assume that they are identical, at least so far as their economic value is concerned.

Black heart birch is found in the same forest as the other two, but is particularly plentiful on the West Coast. There is also a considerable quantity at the Blue Mountains in the Pomahaka district.

In size this tree occupies an intermediate place between the red and silver birches. It grows to a height of from seventy to one hundred feet, with a straight, clear trunk fifty to eighty feet long, and two feet six inches to five feet diameter. Two trees lately measured at Tuapeka Mouth were respectively seventy-two and seventy-four feet from the butt to the lowest branches. Two logs from the Blue Mountains, lately lying near Stirling, measured respectively forty-seven feet long by two feet two inches in diameter, and thirty-four feet long by three feet nine inches in diameter. They were both quite straight and cylindrical, and without crack or other flaw from end to end. The trunks from which those logs were cut measured fifty or sixty feet, but there are many in the same bush eighty feet high to the lowest branch.

Judging from the annual rings, this is the fastest growing tree in Otago. A trunk three feet in diameter is estimated to be 150 years old. In some cases there are only three or four rings in an inch, which shows it to have a growth almost equal to that of oak, elm, or beech, the fastest growing English trees. Black heart birch grows well under cultivation. There are a number of healthy young plants in private gardens in Dunedin. So far as I can ascertain, this tree is not subject to heart-shake or decay.

Black heart birch has, when young, a thin smooth bark of a light grey colour, like kamai, and quite free from the horizontal markings that occur in silver birch. It gets darker, rougher, and thicker

with age like the latter, but never attains to the thickness or roughness of the red birch bark. The leaf of this tree is easily distinguished. It is of an oval or pear shape from one-quarter to seven-eighths of an inch in length, and entire on the edge. The size of the leaf does not change with the growth of the tree, but the same forest produces all sizes. The largest and smallest specimens I have seen are both from Five Rivers.

The wood of the black heart birch is quite different from that of its two congeners. It is of a grey or yellowish ground colour, with dark streaks, and heart, coarse in the grain, stringy and very tough. Some samples resemble very much English elm, and others English ash. The heart-wood generally runs in star-like points towards the circumference, and there is frequently a well-defined and handsome figure in the boards. Full-grown trees have from one and a half to three and a half inches of sap all round.

Until done lately by me, the strength of this timber was never tested. As will be seen by the Tables it occupies a high place, and it is also remarkably stringy and tough. Black heart birch is rather hard and stiff for joiner-work, but is well adapted for framing and similar purposes where strength is required. Some of the figured samples would make handsome furniture.

The lasting properties of black-heart birch have never been thoroughly tested. It has scarcely been tried at all in Otago, and the experience in other Provinces is very limited. Dr. Hector instances a

fence in the Province of Wellington that was in good preservation after being erected 20 years, which is almost the only record I know of its durability. I have seen fencing posts of black heart birch that had been a considerable time in the ground, at Mount Somers, and other places in Canterbury; they were generally in good condition. I could not get trustworthy information as to their age, but there was no doubt as to the identity of the timber.*

GENERAL.

This completes a description of the known Otago trees that yield building materials in the proper sense of the term. There are many smaller trees and shrubs capable of producing useful and ornamental woods, but their consideration would extend my paper beyond reasonable limits, so I must leave them out. Lists of these, with their properties and uses, will be found in the Jurors' Reports of the New Zealand Exhibition, and Captain Campbell-Walker's Forest Report.

CHAPTER VII.

RECAPITULATION.

IN recapitulating the leading points of my subject, it will be necessary to revert shortly to the general properties of timber referred to at the outset, and consider the peculiarities of our native products in the order then given.

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* For additional remarks, see Note, page 217.

Dimensions.—Table No. VII. gives the ordinary dimensions, amount of sap-wood, and approximate age of the principal Otago trees. It shows that, class for class, they are equal in size to those in other countries. The kowhai, rata, manuka, kamai, and black heart birch are on an average as large, if not larger, than oak, ash, elm, and beech, the English timbers for which they are substitutes, and, with the exception of yellow pine and cedar, all our pines are considerably larger and more productive than their European and American prototypes. In like manner we show that the growth is more rapid in New Zealand than most other countries that produce ordinary building timber; consequently the reproduction of native trees, if it can be successfully accomplished, is more profitable than the introduction of foreign ones.

Felling.—The proper season for felling timber in New Zealand is not yet fully determined. The late Mr. Balfour said—"probably it may be found that mid-summer is the best;" but Professor Kirk gives a decided opinion in favour of winter felling. He fixes April to August as the most suitable time in all the forests south of Banks Peninsula. I have no doubt Professor Kirk is correct in considering this the season in which the trees are freest from sap, for the distinctness of the annual rings in most Otago timbers shows a decided period of repose in the growth. Still it is quite possible that a similar condition exists during the two summer months, December and January, and I would have little hesitation in including them in the felling season.

The only well authenticated proof I have obtained of the superiority of winter felling in New Zealand is given in Mr. Horman's fence, at Makarewa, already referred to. All the black pine posts erected in the winter of 1861 are still in good preservation, while those felled and erected a few months subsequently, were more or less decayed some years ago. Assuming that ripe trees only are felled, and that none of the sap-wood is used, the time for felling timber is, within certain limits, of secondary importance to its subsequent seasoning and desiccation.

Seasoning.—The simplest way of obtaining a fair amount of seasoning in New Zealand would be to bark the trees in spring, cut them in the following winter, then slab the logs and let them lie in a running stream for a few weeks; or, what is better, let the sawn scantlings be submerged. There is little trouble in doing this when the timber is cut up in the bush as at Catlins River and Southland. After having the sap washed out in this way, the timber should be thoroughly dried under cover in open sheds.

Table VIII., which gives the results of some experiments I made, shows the absolute necessity of seasoning;—it gives the weight of water in a cubic foot of green timber, and the tranverse shrinkage in boards twelve inches square and half an inch thick. The results may be accepted as a fair indication of what will be obtained in practice, for the samples were picked heart-wood, cut radially to prevent warping; but they were taken from green

logs and subjected to severe drying at a fire, and in the hot air of the Turkish baths. It will be seen that the greatest contraction is in ribbon-wood, next the red birches, and after that the hardwoods generally; the least is in black and white pine. It is worth noticing that English oak and New Zealand red birch, members of the same botanical family, are both given to excessive shrinkage. I should add that the results in Table VIII. are not higher than would be obtained from European and American timbers of the same class.

As the twelve-inch samples were too short to test the contraction endwise, I did so by fixing long three by half-inch green battens in the sun on a wall. After being exposed for four weeks in exceptionally hot, dry weather, they were found to have shrunk as follows:—

White pine and totara ...	0·30 of an inch in 20 feet.		
Red pine	0·23	„	„
Kauri	0·11	„	„

Of course the kauri was somewhat dryer than the others to commence with. As there is no record of similar experiments having been made with the timbers of other countries, I tested a few imported samples: they were first soaked in water to bring them to something like their original condition, but this seemed to have little effect, for they did not expand to any measurable extent. In re-drying, however, some of them shrunk as follows:—

American yellow pine ...	0·21 of an inch in 20 feet.		
„ clear pine ...	0·12	„	„
Baltic red deal	0·12	„	„

Although not very conclusive, we may infer from those experiments that our timbers do not shrink more endwise than foreign ones of the same class. The importance of seasoning timber has hitherto been very much overlooked in New Zealand. Instead of using well-dried heart-wood from mature trees that are felled at the proper season of the year, we put into our houses wet sap-wood from young trees that are felled when most convenient, probably in their juiciest state; and, to increase the evil, the timber is painted at once, so that all the juices are retained to ferment, and thus breed corruption. It frequently happens that the timber for some of our best buildings is standing in the forest after the work has been commenced. Colonial timbers have fallen into disrepute solely on account of being used in a green state alongside foreign ones that are well seasoned. As a matter of fact, many of the latter are considered worthless in their own country for the same reason. It may therefore be set down as an axiom that no timber is good in the country that produces it.

Strength.—The late Mr. Balfour conducted a series of experiments on the strength of New Zealand woods at the New Zealand Exhibition of 1865. So far as they went these experiments were very satisfactory, but he himself admitted that they were not exhaustive, and suggested the further investigation of the subject by the General Government. A collection of timber specimens was made for this purpose in 1872, but the experiments have not yet been made. In reporting on this subject Mr. Bal-

four said :—" New Zealand woods compare very fairly with those which we have been accustomed to consider as standards, the absolute strength of very many being above that of British oak, and all being stronger than elm. * * * New Zealand woods are certainly for the most part short in the grain and break with little warning. There are a number of valuable exceptions, but it will be observed that the ratio of safe load to breaking weight is high, which to a great extent compensates for this peculiarity."

Mr. Brunton, C.E., Invercargill, tested four samples each of black pine and totara on ten feet bearings. One of the former was eight, and all the others four inches square. The large black pine piece broke with six and three-quarter tons, and the average breaking weight of the smaller pieces was—for black pine, twenty-three and a half hundredweights; and totara, twenty and three-quarter hundredweights. When worked out in the same manner, this makes black pine fifty-three per cent., and totara thirty-one per cent. weaker than the mean of Mr. Balfour's experiments with small samples.

These and other discrepancies and doubts, and the absence of any experiments whatsoever on several varieties, induced me to institute a series of tests at Dunedin. Mr. Balfour's experiments were made with pieces twelve inches long and one inch square, supported at one end, the weight being applied at the other. My pieces were two feet long by one inch square, supported at both ends, and loaded in the centre. It takes twice the weight to

break a beam in this latter position, although twice as long, consequently my weights were proportionately heavier—the actual weights employed are given in Table IX.—but in order to correspond with Balfour and so facilitate comparison, the half-weights only are given in Table X.—the one intended to be used in calculating the strength of beams. The Exhibition experiments were made with a machine which recorded the greatest weight carried with unimpaired elasticity, and the deflection when it was applied. This gives the data from which the elasticity of the timber can be calculated. It also gave the breaking weight and deflection at the moment of fracture, from which the ultimate strength is calculated. My samples were broken with actual weights, applied gradually, so the data for elasticity could not readily be obtained. I may, however, remark that this is not an important want, as the question of theoretical elasticity seldom enters into the constructor's calculations; indeed, the exact method of measuring this property has not yet been determined.

As shown by Table IX., upwards of 400 pieces of various kinds of timber were tested under my direction. They were obtained from all parts of the Colony. Generally the samples were from ordinary market stuff, picked up promiscuously in the timber yards, therefore the results can be considered a fair average of what may be expected in practice. The samples were carefully prepared and tested by Mr. Buchanan, and the results worked out and checked by other officers of the Public

Works Department. So far as they go I have every confidence in the accuracy of the experiments and the deductions made from them. By referring to Balfour's Tables in the Jurors' Reports of the New Zealand Exhibition, it will be seen that there is a great difference between his results and mine in many of the more important timbers, the following being the most conspicuous examples :—

Name of Timber.	Balfour.		Blair.	
	No. of Pieces Tested.	Breaking weight. Pounds.	No. of Pieces Tested.	Breaking weight. Pounds.
Silver Birch ...	8	158·20	11	175·50
Red Pine	16	140·20	25	175·44
White Pine ...	11	106·00	4	166·62
Red Birch ...	7	202·50	99	156·84
Totara	17	133·60	10	142·50
Kauri	12	165·50	34	137·17

In the case of the four pines above named, Balfour's samples and mine came from much the same localities throughout the Colony. His silver birch came altogether from Wakatipu ; ten of my samples came from Catlins River, and one from the Blue Mountains.

The low value given to red birch by my experiments is a serious matter, for it has hitherto been regarded as the strongest native timber suitable for beams, and numerous important structures have been erected on this supposition ; it is, therefore, necessary to treat the subject in detail. The following table gives the particulars in each set of experiments :—

RED BIRCH.

BALFOUR'S EXPERIMENTS.

Locality.	No. of pieces tested.	Breaking Weight.			Remarks.
		Mean.	Maximum.	Minimum.	
Wakatipu ...	3	232	250	211	
Wellington ...	3	199·8	225	135	
Unknown ...	1	122·5	...	...	Experiment made at Sydney.
Averages ...	7	202·5	250	122.5	All Balfour's experiments

BLAIR'S EXPERIMENTS.

Locality.	No. of pieces tested.	Breaking Weight.			Remarks.
		Mean.	Maximum.	Minimum.	
Grey Valley, No. 1	10	164·75	186	142	From a tree 3ft. 6in. dia.; estimated age, 264 years.
Do. do. No. 2	10	163	185	144.5	Do. 2ft. 6in.; do. 240 yrs.
Do. do. No. 3	10	141·8	162	123	Do. 3ft.; do. 310 years.
Do. do. No. 4	10	158·1	172	129	Do. 3ft.; do. 230 years.
Averages ...	40	156·91	186	123	All the West Coast samples.
Wakatipu ...	12	192·79	262·5	171	
Five Rivers ...	11	146·82	193	115·5	
Catlins River ...	33	147·36	210	105	
Blue Mountains	3	154	189	119	
Averages ...	59	156·83	262·5	105	All the East Coast samples.
Averages ...	99	156·86	262·5	105	All Blair's experiments.

In addition to the advantage of a greater number of experiments, the above table shows such a uniformity in my results as would indicate them to be a fairer average of the strength of red birch than those determined by Mr. Balfour.

The Foreign timbers enumerated in Table IX., were broken chiefly for the purpose of comparing their fractures with those of the native varieties, but in a few cases, notably Californian redwood and Oregon pine, all the results will be useful, as there are no other recorded experiments on those two timbers. It is worth noticing that there is no ground for the popular impression as to the great strength of Oregon pine, so extensively used in New Zealand; although fibrous and elastic, its absolute strengh is less than that of any of the Otago pine woods.

The difference in the results obtained from the few experiments already made on New Zealand timbers points to the necessity of a thorough investigation of the whole subject, as recommended by Mr Balfour in 1865. The experiments hitherto made have been on pieces an inch square. I observe that Mr Laslett, who tested the strength of most of the principal woods in the world for the Admiralty, used pieces six feet long and two inches square, supported at both ends. As his results will probably be the standard in future, any further experiments in New Zealand should be on the same scale.

Table X., hereto appended, gives the main results of Mr Balfour's, and of my own experiments, put

into a more popular form than the one originally adopted by him, which was intended for professional men. My table simply gives the *weight*, *strength*, *elasticity*, *toughness*, and *safety* of the principal Otago timbers, with examples of well-known varieties from other countries. In the New Zealand timbers the "weight" and "elasticity" columns are entirely from Balfour's experiments; the "strength" is either his or mine, according to what seemed the most trustworthy results in each case; and the two last columns, "toughness" and "safety," are entirely from my experiments. The two latter are of little scientific value, but they may be found useful in making comparisons, and otherwise determining the general character of the timber. They also give a rough indication of the extent to which a beam can be loaded with safety.

Table XI., the last of those I have prepared, is intended as a guide in the selection of native timber for special purposes. It gives an abstract of the properties and uses of the various kinds referred to in the paper.

Conclusion.

In conclusion, I claim to have shown that Otago, and New Zealand generally, is well provided with good timber suitable for all the purposes of the constructive and mechanical arts; but, hitherto, our resources have not been utilised to the best advantage. We are still importing £120,000 worth annually from foreign countries, and no practical steps have been taken to conserve our natural sup-

plies, nor to provide artificial ones when these are exhausted. Neither have the properties of the timbers been fully investigated. As this is a subject of the utmost importance to the Colony at large, I trust that in future it will receive more public attention than has been bestowed on it in the past.

NOTE ON CHAPTER VI.

Black Heart Birch.—Just as these sheets were going through the press, an agitation arose in the Oxford District about the use of this timber in railway works, and at a public meeting of the residents it was resolved to collect information regarding its durability. The result has been communicated to me by Mr. Ingram, as follows :—There is a hut at Mr. Pearson's station, Burnt Hill, erected in 1851, the piles of which are still in good preservation. Mr. Higgins, of Tara, has had Black Heart Birch in the ground for eighteen years without showing symptoms of decay. Mr. Chapman, of Springbank, put this timber into stock-yard posts sixteen years ago, and the heart-wood is still quite sound. Similar testimony is given by Mr. Blackett, Rangiora, who has used the timber for fifteen years ; Mr. D. Fisher, who has used it for twenty years ; and Mr. Denby, who has used it for eighteen years. Mr. Burt, Rangiora, produces a post that has been in the ground fifteen years, and Mr. C. A. White a piece of a tramway-sleeper seventeen years old—the timber in both cases being quite sound. Mr. J. Evans Brown, M.H.R., pronounces the Oxford birch durable ; and the Hon. Edward Richardson, C.M.G., says : "I am quite satisfied that under certain conditions the heart of black birch is almost imperishable, comparatively speaking, and infinitely superior to the black pine or totara of the Middle Island. The conditions I refer to are—first, that the timber be cut at the proper season of the year ; and, secondly—and probably more important—that the timber is grown on tolerably stiff soil, and not subject to be flooded."

The above evidence is quite sufficient to warrant us in concluding that black birch is a durable timber.

W. N. B.

TABLE VI.

NAMES OF OTAGO TIMBER TREES.

HARD WOODS.

No.	Popular Name.	Synonyms.	Authority	Remarks.
1	BLACK MAPAU—			
		Pittosporum tenuifolium ...	Hooker ...	Botanical name.
		Kohuhu	Maoris ...	According to Colenso.
		Tawhiwhi	"	" " "
		Tarata	"	" " Lindsay.
		Tipau	"	" " Buchanan.
		Maple	Settlers ...	Occasionally so called.
2	BLACK MAPAU—			
		Pittosporum colensoi ...	Hooker ...	Botanical name.
		Mapauriki	Maoris...	According to Cunningham.
		Tarata	"	" " Kirk.
		Tipau	"	" " Buchanan.
		Maple	Settlers...	Occasionally so called.
3	TURPENTINE—			
		Pittosporum eugenioides ...	Hooker ...	Botanical name.
		Tarata	Maoris ...	According to Colenso.
		Kohuku	"	" " Kirk.
		White mapau	Buchanan	Almost as common as "turpentine."
		Maple	Settlers...	Occasionally so called.
4	RED MAPAU—			
		Myrsine urvillei	Hooker ...	Botanical name.
		Tipau	Maoris ...	According to Colenso.
		Mapau	"	" " "
		Maple	Settlers...	Occasionally so called.
5	WHITE MAPAU—			
		Carpodetus serratus ...	Hooker ...	Botanical name.
		Piripiriwhata	Maoris ...	According to Cunningham.
		Tawiri	"	Balfour, quoting Buchanan in Jurors' Report, N.Z. Exhibition. Not seen elsewhere.
		Kohu-kohu	"	
6	MANUKA—	... ...	...	Also native name, Colenso.
		Leptospermum scoparium ...	Hooker ...	Botanical name.
		Kahikatoa	Maoris ...	According to Colenso.
		Tea or ti tree	Settlers...	... ...
		Red manuka	"	... ...

HARD WOODS—*Continued*,

No.	Popular Name.	Synonyms.	Authority	Remarks.
7	MANUKA—	... ...	...	Also native name.
		Leptospermum ericoides ...	Hooker ...	Botanical name.
		Manuka-rau-riki	Maoris ...	According to Colenso.
		Rawiri	„	„ „ Kirk.
		Tea or ti tree	Settlers ...	... ...
		White manuka	„	... ...
8	RATA—	... ...	...	Also native name, Lyall.
		Metrosideros lucida ...	Hooker ...	Botanical name ...
		Ironwood	Settlers ...	... ...
9	KOWHAI—	... ...	...	Also native name, Colenso.
		Sophora tetraptera ...	Hooker ...	Botanical name.
		New Zealand acacia ...	Settlers ...	According to Colenso.
10	FUCHSIA—	*Fuchsia excorticata*	Hooker ...	Botanical name.
		Konini	Maoris ...	According to Buchanan.
		Kohutuhutu	„	„ „ Colenso.
		Kotukutuku	„	„ „ Colenso.
11	BROADLEAF—	*Griselinia littoralis* ...	Hooker ...	Botanical name.
		Pukatea	Maoris ...	According to Colenso.
		New Zealand laurel ...	Settlers ...	Frequently used in Australia.
12	KAMAI—	... ...	...	Also native name.
		Weinmannia racemosa ...	Hooker ...	Botanical name
		Tawhero...	Maoris ...	According to Lyall.
		Tawero	„	„ „ Kirk.
		Karmahi...	„	„ „ Hector.
		Towai	„	„ „ Colenso.
		Tawai	„	„ „ Cunningham.
		Black birch	Settlers ...	So called at Catlins river.
		Red birch	„	„ in North Island and South Otago.
		Brown birch	„	West Coast and Nelson.
13	POKAKO—	... ...	...	Also native name, Colenso.
		Elæocarpus hookerianus ...	Hooker ...	Botanical name.
		Hinau	Maoris ...	According to Cunningham.
14	POKAKO—	... ...	...	Also native name, Colenso.
		Elæocarpus dentatus ...	Hooker ...	Botanical name.
		Hinau	Maoris ...	According to Raoul.

HARD WOODS—*Continued.*

No.	Popular Name.	Synonyms.	Authority	Remarks.
15	RIBBON-WOOD—			
		Plagianthus betulinus ...	Hooker ...	Botanical name.
		Whau-whi	Maoris ...	According to Hector.
		Lace-bark tree	Settlers ...	„ „ Buchanan.
16	RIBBON-WOOD—			
		Hoheria populnea ...	Hooker ...	Botanical name.
		Howhere...	Maoris ...	According to Colenso.
		Houi	„	
		Whau-whi	„	
17	RIBBON-WOOD—			
		Pennantia corymbosa ...	Hooker ...	Botanical name.
		Kaikomako	Maoris ...	According to Colenso.
18	GRASS TREE—			
		Panax crassifolium ...	Hooker ...	Botanical name.
		Horoeka	Maoris ...	According to Colenso.
		Lance-wood	Settlers ...	... ...
		Umbrella-tree	„	... ...

SOFT WOODS.

No.	Popular Name.	Synonyms.	Authority	Remarks.
1	CEDAR—	*Libocedrus bidwillii*, or *L. doniana*	Hooker ...	Botanical names.
		Kawaka	Maoris ...	Applied to *L. doniana*, according to Colenso.
		Pahautea	„	Applied to *L. bidwillii*, according to Colenso.
		Moko-piko	„	Do. do. according to Bidwill.
		Totara-kiri-kotukutuku ...	„	Applied to *L. doniana*, according to Mantell.
		Arbor vitæ	Settlers ...	... ...
		Cypress	„	... ...
2	MIRO— ...	... ...	...	Also native name.
		Podocarpus ferruginea ...	Hooker ...	Correct botanical name.
		Podocarpus spicata ...	...	Erroneously so called in Jurors' Reports N.Z. Exhibition.
		Toromiro	Maoris ...	... ...
		Black pine	Settlers ...	Old name now obsolete.

SOFT WOODS—*Continued.*

No.	Popular Name.	Synonyms.	Authority	Remarks.
3	TOTARA—	... ...	...	Also native name.
		Podocarpus totara ...	Hooker ...	Botanical name.
4	BLACK PINE—			
		Podocarpus spicata ...	Hooker ...	Correct botanical name.
		Podocarpus ferruginea ...	...	Erroneously so called in Jurors' Reports N.Z. Exhibition.
		Matai	Maoris ...	Now coming into use as a popular name.
		Mai	„	According to Cunningham.
		Black rue	Settlers ...	According to Hector and Buchanan.
5	WHITE PINE—			
		Podocarpus dacrydioides ...	Hooker ...	Botanical name.
		Kahikatea	Maoris ...	According to Colenso.
		Kaikatea	„	Probably a corruption of the preceeding name.
		Swamp pine	Settlers ...	In North Island.
6	RED PINE—			
		Dacrydium cupressinum ...	Hooker ...	Botanical name.
		Rimu	Maoris ...	Now becoming popular also.
7	YELLOW PINE—			
		Dacrydium colensoi ...	Hooker ...	Botanical name.
		Manoao	Maoris ...	According to Colenso.
		Silver pine	Settlers ...	So called on the West Coast.
		Tar-wood	„	So called in vicinity of Dunedin.
8	WESTLAND PINE			
		Dacrydium westlandicum ...	Kirk ...	Botanical name.
		Yellow pine	Settlers ...	According to Kirk.
		Silver pine	„	According to Kirk.
		White silver pine	„	According to Kirk.
		Huon pine	„	H. Gordon.
9	SILVER PINE—			
		Dacrydium intermedium ...	Kirk ...	Botanical name.
		Yellow silver pine ...	Settlers ...	According to Kirk.
		Mountain pine	„	„ „ H. Gordon.
10	CELERY PINE—			
		Phyllocladus alpina ...	Hooker ...	Botanical name.
		Tanekaha	Maoris ...	According to Colenso.
		Toa-toa	„	„ „ „
		Hickory	Settlers ...	So called in Southland.

SOFT WOODS—*Continued.*

No.	Popular Name.	Synonyms.	Authority	Remarks.
11	Silver Birch—	... ...	...	Most popular name in Otago.
		Fagus menziesii	Hooker ...	Botanical name.
		Tawai	Maoris ...	According to Colenso.
		Tawhai	„	„ „ „
		Towai	„	„ „ Balfour.
		White birch	Settlers...	Frequently so called in Otago.
		White kamai	„	So called in South Otago.
12	Red Birch—	... ...	...	Common throughout Otago and South Island generally.
		Fagus fusca	Hooker ...	Botanical name.
		Hututawhai	Maoris ...	According to Kirk.
		Towai	„	„ „ Balfour
		Tawai	„	„ „ Bidwill
		Tawhai-rau-nui	„	„ „ Colenso.
		Black birch	Settlers...	So called in the Northern provinces and by Balfour, but not in Otago.
		Red Kamai	„	So called in South Otago.
13	Black Heart Birch—			
		Fagus solandri, or *F. cliffortioides*	Hooker ...	Botanical names.
		Tawhai	Maoris ...	According to Colenso.
		Tawai-rau-riki	„	„ „ Geological Survey.
		White birch	Settlers...	Commonly applied when the timber is mostly white.
		Silver birch	„	Occasionally so called.
		Black birch	„	Very common in all the South Island.

TABLE VII.

APPROXIMATE DIMENSIONS AND GROWTH OF THE PRINCIPAL TIMBER TREES OF OTAGO.

Name.	Ordinary Dimensions.		Approximate Age.	No. of Annual Rings in an Inch.	Thickness of Sap-wood.
	Length.	Diameter.			
	Feet.	Inches.	Years.		Inches.
Manuka - -	30 to 60	12 to 24	100 to 250	20	½
Rata - - -	30 to 40	24 to 48	200 to 450	19	½
Kowhai - -	20 to 40	18 to 36	140 to 270	15	1 to 3
Broadleaf - -	15 to 25	36 to 72	340 to 700	19	2
Pokaka - -	60	30	200	14	4
Cedar - -	20 to 40	18 to 42	150 to 400	15 to 28	1 to 4
Miro - - -	20 to 50	18 to 36	150 to 300	20	3 to 12
Totara - -	20 to 80	36 to 60	470 to 800	26	3 to 6
Black pine - -	20 to 40	24 to 42	270 to 400	23	2 to 4
White pine - -	40	30 to 48	370 to 600	25	12
Red pine - -	20 to 80	30 to 48	400 to 650	27	3 to 6
Yellow Pine -	10 to 20	30	300	21	1
Silver birch -	20 to 80	20 to 45	150 to 330	12 to 19	3½
Red birch - -	20 to 60	30 to 60	130 to 300	10 to 17	1 to 4
Black-heart birch	50 to 80	24 to 45	80 to 180	6 to 9	3

TABLE VIII.

SEASONING OF OTAGO TIMBERS.

Name.	Weight per Cubic foot. Green. Pounds.	Weight of Moisture in a Cubic Foot of Green Timber. Pounds.	Weight per Cubic Foot, Seasoned. Pounds.	Shrinkage in Boards 12in. square by ½in. thick. Inches.	Remarks.
Turpentine - -	69·216	29·232	45·074	0·70	
Rata - - -	72·041	15·401	63·314	0·65	Old log.
Kowhai - -	79·019	27·860	57·767	0·93	
Broadleaf - -	70·971	22·745	52·511	0·50	
Kamai - -	61·377	27·617	38·717	0·80	Mean of two—heart of log partly seasoned.
Pokaka (*E. hookerianus*)	57·929	22·875	38·368	0·53	Old log partly seasoned.
" "	63·491	33·229	32·919	0·50	Green.
Ribbon-wood (*P. populnea*)	59·842	28·059	39·386	1·22	
Kauri - - -	45·709	8·105	39·830	0·34	Out of log partly seasoned.
Cedar - - -	47·750	22·978	28·611	0·35	
" - - -	61·405	38·163	26·306	0·72	
Miro - - -	70·189	31·121	44·215	0·72	
" - - -	73·321	33·949	44·426	0·62	
" - - -	71·554	32·486	42·827	0·54	
" - - -	62·208	21·291	47·482	0·86	Partly seasoned.
Totara - -	49·783	17·012	36·310	0·60	
" - - -	56·715	19·138	42·228	0·68	Old block.
" - - -	50·482	16·368	37·603	0·57	
Black pine - -	75·534	30·456	46·862	0·23	
" " - -	77·798	32·948	47·508	0·34	
White pine - -	38·921	11·698	28·636	0·30	
" " - -	43·899	16·896	29·505	0·52	
Red Pine - -	43·117	11·533	34·294	0·48	From Taieri Mouth
" " - -	71·136	34·004	42.775	0·82	
Yellow pine -	55·461	11·952	46·162	0·35	
Celery pine -	47·170	17·503	31·588	0·38	Mean of two, old logs partly seasoned.
Silver birch -	52·621	26·269	28·446	0·45	
Red birch - -	39·620	7·574	40·358	1·17	
" " - -	58·176	29·084	34·124	0·92	
" " - -	41·000	7·244	40·648	0·23	Old sample.
" " - -	68·909	34·590	36·330	0·66	Mean of six samples from Grey Valley.
Black-heart Birch	53·485	16.738	40·292	0·54	

TABLE IX.

STRENGTH OF TIMBERS.

ABSTRACT RESULTS OF EXPERIMENTS MADE AT DUNEDIN IN 1878.

Name.	Number of Samples Tested.	Breaking Weight. Pounds.			Deflection. Inches.			Length of Fracture. Inches.		
		Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
New Zealand Timbers—										
Ironwood	4	578·5	629	501	1·95	2·5	1·5	7·25	12	1·5
Miro	7	440·28	523	339	1·54	2·0	1·3	12·07	15	8
Black Pine	28	384·03	553	210	1·11	2·1	0·5	8·21	18·25	1
Silver Birch	11	351	436	297	1·25	2·2	0·7	10·72	14	7
Red Pine	25	350·88	448	238	1·25	1·8	0·5	8·62	17	0·5
Black Heart Birch	15	339·53	420	227	1·58	2·0	1·3	3·36	9	1
White Pine	4	333·25	358	308	1·07	1·3	0·7	6·75	10	2
Kamai	37	314·7	476	210	1·73	3·2	0·8	5·62	11	2
Red Birch...	99	313·73	525	210	1·56	2·7	0·8	7·45	15	0·5
Totara	10	285·1	344	224	1·50	2·1	1	7·25	12	1
Kauri	34	274·34	374	196	1·20	2·3	0·7	5·38	15	0·25
Otago Cedar	26	199·96	280	140	1·47	2·9	0·5	5·47	13	0·12
English and Foreign Timbers—										
Australian Ironbark ...	11	543·09	668	406	1·04	1·6	0·6	4·77	10	0·5
„ Bluegum ...	3	518·66	648	396	1·03	1·3	0·8	2·83	6	1
„ Greygum ...	4	446·25	548	345	1·18	1·4	1	0·87	1·5	0·5
„ Stringybark ...	4	431·75	464	392	1·35	1·6	1·2	2·37	5	0·5
English Ash	9	388·33	522	336	1·66	2·2	1·0	8·44	15	5
Tasmanian Blackwood ...	7	387·59	474	308	1·29	2·1	0·75	6·64	13	0.25
Baltic Pitch Pine	8	377·87	425	350	1·02	1·1	0·7	7·94	14	2
Western Australian Jarrah ...	9	352·11	392	283	1·2	1·7	0·5	5·72	13	1
Baltic Deal	10	315·8	350	266	1·13	1·3	0·9	5·1	9	0·5
American Oak	3	310·	316	302	1·66	1·7	1·6	9·83	11	7·5
Baltic Spruce	7	294·28	322	252	1·08	1·2	1·0	3·43	5	0·5
Californian Redwood ...	13	285·15	360	210	0·7	0·8	0·6	1·58	9	0·25
Oregon Pine	22	279·36	451	216	0·93	1·3	0·75	5·06	15	0·5
Sydney Cedar	3	256·33	266	251	1·13	1·2	1	8·66	12	7
American Clear Pine ...	3	184	195	178	1·06	1·1	1	7·33	13	3

NOTES ON TABLE IX.

The "Breaking Weight" given in the first column is the weight in pounds required to break pieces two feet long and one inch square, supported at both ends, and loaded in the centre.

The "Deflection" was taken at the instant of fracture.

The "Length of Fracture" was measured between the extreme points to which the timber was broken or torn.

TABLE X.

WEIGHT AND STRENGTH OF OTAGO TIMBERS, WITH ENGLISH AND FOREIGN EXAMPLES.

Name.	Weight per cubic foot, dry.	Strength.	Elasticity.	Toughness.	Safety.	Experimenter.
	W	S	E	T	Y	
Otago Timbers—						
Black Mapau, *P. tenuifolium* ...	60·14	243.00	215·20			Balfour
Red Mapau	61·82	192·40	169·88			"
White Mapau	51·24	177·60	166·86			"
Manuka	59·00	239·00	239·50			"
Rata	65·13	196·00	244·20			"
Kowhai	55·11	207·50	198·05			"
Kamai	38·75	157·35		544·4	1768	Blair
Pokaka, *E. dentatus*	35·03	125·00	200·70			Balfour
Cedar	39·69	99·98		293·9	1094	Blair
Miro	49·07	220·14	230·24	678·0	5314	"
Totara	35·17	142·50	124·60	427·6	2067	"
Black Pine	40·74	192·01	156·22	426·3	3153	"
White Pine	30·43	106·00	127·10			Balfour
Red Pine	39·25	175·44	143·38	438·6	3024	Blair
Silver Birch...	38·99	175·50	116·00	438·7	3763	"
Red Birch	48·62	156·84	219·50	489·4	2335	"
Black Heart Birch	40·00	169·76		536·4	1141	"
English and Foreign Examples—						
Australian Ironbark	70·92	282·70	297·00			Balfour
" "		271·54		564·8	2590	Blair
" Bluegum	60·66	214·80	259·60			Balfour
" "		259·33		534·2	1468	Blair
" Greygum... ...		223·12		526·6	388	"
" Stringybark ...	60·67	205·50	239.30			Balfour
" "		215·87		582·8	1023	Blair
English Oak	51·72	176·40				Laslett
" Ash	46·00	188·50				"
" "		194·16		644·6	3277	Blair
Tamanian Blackwood ...	45·99	232·80	218·80			Balfour
" "		193·79		499·9	2573	Blair
Riga Fir	33·81	131·20				Laslett
English Elm	34·87	86.00				"
Kauri	34·31	157·42				"
"	38·96	165·50				Balfour
"		137·17		329·2	1478	Blair

$\frac{KBD^2}{L}$ $\frac{8KBD^2}{L}$ B = breadth ...

$\frac{2KBD^2}{L}$ $\frac{12KBD^2}{L}$ D = depth ...

L = length ...

K constant ...

TABLE X.—(*Continued*).

Name.	Weight per cubic foot, dry.	Strength.	Elasticity.	Toughness.	Safety.	Experimenter.
	W	S	E	T	Y	
Baltic Pitch Pine		188·93		385·4	3000	Blair
Jarrah	63·12	150·00				Laslett
"		176·05		422·5	2014	Blair
Baltic Deal		157·90		354·8	1610	"
American Oak		155·00		514·6	3047	"
Baltic Spruce		147·14		317·8	1009	"
Californian Redwood ...		142·57		199·6	450	"
Oregon Pine		139·68		259·8	1413	"
Sydney Cedar	28·86	120·75	134·46			Balfour
" "		128·16		289·6	2220	Blair

NOTES ON TABLE X.

The "Strength" given in column S is the weight in pounds required to break pieces twelve inches long and one inch square supported at one end and loaded at the other.

"Elasticity" is the greatest weight in pounds carried with unimpaired elasticity, divided by the deflection caused by it in inches, the specimen being the same size and loaded as above.

"Toughness" is the breaking weight given in Table IX., multiplied by the deflection caused by it in inches at the instant of rupture.

"Safety" is the breaking weight given in Table IX., multiplied by the length of fracture.

Rule.—To find the breaking weight of a beam from the table, multiply together eight times the breadth of the beam in inches, the square of its depth in inches, and the tabular number S; the result divided by the distance between the supports in feet, gives the breaking weight in pounds distributed over the entire length of the beam.

Example.—A kowhai beam twelve feet long between the supports, twelve inches deep and six inches broad, will break with 53 tons 7 cwts. 16 lbs, thus—

$$\frac{8 \times 6 \times 12 \times 12 \times 207{\cdot}5}{12} = 119{,}520 \text{ lbs.} = 53 \text{ tons } 7 \text{ cwts. } 16 \text{ lbs.}$$

When the load is confined to the centre, the beam breaks with half this weight.

TABLE XI.

PROPERTIES AND USES OF OTAGO TIMBERS.

APPROXIMATELY IN ORDER OF SUPERIORITY AND FITNESS.

Durability.	Strength.	Elasticity.	Toughness.
Kowhai	Black Mapau	Rata	Miro
Broadleaf	Manuka	Manuka	Kamai
Fuchsia	Miro	Miro	Black Heart Birch
Black Pine	Kowhai	Red Birch	Kowhai
Totara	Rata	Black Mapau	Red Birch
Cedar	Red Mapau	Pokaka	Silver Birch
Kamai	Black Pine	Kowhai	Red Pine
Red Birch	Silver Birch	Red Mapau	Totara
Yellow Pine	Red Pine		Black Pine
	Black Heart Birch		

Weight.	Lightness.	Hardness.	Softness.
Kowhai	Cedar	Rata	Silver Birch
Black Pine	Silver Birch	Manuka	White Pine
Miro	White Pine	Fuchsia	Cedar
Rata	Celery Pine	Grass Tree	Celery Pine
Red Pine	Pokaka	Kowhai	Red Birch
Broadleaf	Red Birch	Broadleaf	
Turpentine	Red Pine	Kamai	
Yellow Pine	Totara	Black Pine	

ENGINEERING PURPOSES.

Piles.	Beams.	Sleepers.	Planking.
Kowhai	Kowhai	Black Pine	Black Pine
Black Pine	Rata	Totara	Black Heart Birch
Kamai	Black Pine	Red Birch	Kamai
Totara	Black Heart Birch	Kamai	Red Birch
Black Heart Birch	Kamai	Cedar	
Rata	Red Birch	Black Heart Birch	
Red Birch			
Cedar			

TABLE XI.—(*Continued.*)

Machinery Framing.	Implements and Wheelwright's Work.	Teeth and Bearings.	Patterns.
Manuka Kowhai Miro Red Birch Black Pine	Manuka Kowhai Rata Black Heart Birch Black Pine	Rata Kowhai Manuka Broadleaf	Silver Birch White Pine Cedar Red Birch

BUILDING AND GENERAL PURPOSES.

Fencing and House Blocks.	Framing.	Beams and Joists.	Flooring and Weather Boards.
As per Durability List	All the Pines and Birches.	Miro Black Pine Silver Birch Red Pine Black Heart Birch Kamai Red Birch	White Pine Silver Birch Red Birch Red Pine Totara

Internal Joiners' Work.	Furniture.	Ship Timbers.	Firewood.
Silver Birch White Pine Red Birch Cedar Totara Black Pine Miro Red Pine	Kamai Black Heart Birch Miro Red Pine Rata Kowhai Pokaka Mapau Red Birch Manuka	Rata Kowhai Manuka Broadleaf Kamai Black Heart Birch	Manuka Rata Kowhai Black Pine Red Birch

SECTION IV.

METALS.

General.

A TREATISE on the building materials of any country or district would not be complete without a reference to its metals. It is principally for this reason that a chapter is devoted to the subject, as the building metals of New Zealand are comparatively little known and altogether undeveloped. It is, however, desirable to record here what discoveries of metallic ores have been made, and to consider what prospect there is of utilising them. The metals most used in the constructive arts are *Iron*, *Copper*, *Lead*, and *Tin*. I shall discuss them briefly in the order here given.

Iron.—The economic iron ores are naturally divided into two classes, determined by their chemical constituents and affinities ; these and their principal sub-divisions being as follows :—

1st. *Oxides.* — Magnetic ores or Loadstones, Hematite or Specular ore, and Brown or Bog ores.

2nd. *Carbonates.*—Spathic or Sparry ores, Black Band Ironstones, and Clay Ironstones.

The amount of metallic iron in the first class ranges from 40 to 70 per cent., and in the second from 25 to 40 per cent. Although the richer ores are extensively used, the greater portion of the iron of Great Britain is manufactured from the poorer kinds. This is in consequence of the latter being more easily reduced. Frequently a mixture of two or more ores is employed with the view of getting the largest return at the minimum cost. As a rule the richest ores produce the best metals. The famous steel blades of olden times—the high-class native iron of India and Japan, and the well-known Swedish bars—are all products of rich ores.

With the exception of black band veins at Collingwood, in Nelson, and a small specimen from Bank's Peninsula, all the New Zealand ores hitherto discovered belong to the higher class. Professor Hutton refers to samples from Marewhenua and Tokomairiro as "Clay Iron ore," but according to Professor Black's analyses they do not contain carbonate of iron, consequently they must be classed with the Oxides.

Numerous deposits of iron ore are found at intervals throughout the whole length of New Zealand, the most plentiful being the well-known iron sand of the goldfields and sea beaches. This sand is found in small quantities in most of the larger rivers, and abounds on the sea-shore of the West Coast of both Islands; also on the South Eastern Coast at Tokomairiro and Stewart Island. The largest deposits occur at Taranaki, where the beach is covered for miles to a depth of several feet.

The compact ores are also well diffused throughout the Colony; the largest deposit being at Para Para, in Nelson, where a hill of hematite or bog ore occurs, estimated to contain nearly 53,000,000 tons of ore. In Otago compact iron ores have been discovered at Marewhenua, Wakatipu, Dunstan, Tokomairiro, and Clutha.

A very complete list of the iron ores discovered in New Zealand, with their properties, is given by Dr. Hector in the Parliamentary Papers of 1873. Professor Black's Reports also gave analyses of a large number. From these documents I have compiled the following table, showing the principal economic iron ores of New Zealand, together with a statement of their character and value, a few examples from other countries being added for comparison :—

OXIDES.

New Zealand Ores.	Per Centage of Metallic Iron.
Magnetite—Sands—	
Buller River, Nelson	59 to 70
Clutha River, Otago	59 to 66
Wakatipu „	53
Mataura River „	61
Stewart Island	57 to 70
Hokitika Beach	54
Taieri „	50 to 53
Taranaki „	56 to 70
Tauranga „	68
Magnetite—Compact Ores—	
1. Manukau, Auckland	70
2. Dunstan Gorge, Otago ...	64

EXAMPLES.

Magnetite—Compact Ores—

Dartmoor, England	57
Rosedale „	36 to 49
Sweden	72

NEW ZEALAND ORES.

Hematite—Sands—

Tuapeka, Otago	64

Hematite—Compact Ores—

3. Wakatipu, Otago	68
4. Dun Mountain, Nelson ...	63
5. Maramarua, Auckland ...	62
6. Clutha, Otago...	46
7. Cromwell „	49

EXAMPLES.

Hematite—Compact Ores—

Whitehaven, England	66 to 69
Ulverstone „	60 to 66
South Wales „	48

NEW ZEALAND ORES.

Brown or Bog Ores—

8. Spring Swamp, Auckland ...	51
9. Raglan „ ...	51
10. Kawau „ ...	48
11. Para Para, Nelson	44 to 56
12. Waihemo Valley, Otago ...	35
13. Marewhenua „ ...	38
14. Tokomairiro „ ...	56

EXAMPLES.

Brown or Bog Ores—

Dean Forest, England	23 to 63
Weardale „	43 to 50
Northamptonshire, England ...	24 to 53
Pennsylvania, America	60

CARBONATES.

NEW ZEALAND ORES.

Black Band—

15. Collingwood, Nelson...	...	35 to 46

EXAMPLES.

Spathic Ores—

Durham, England	...	...	38
Somersetshire, England ...		...	34

Black Bands and Clay Ironstones—

Scotland ...	...	...	...	28 to 41
Yorkshire...	...	...	...	29 to 34
Staffordshire	...	...	...	25 to 41
South Wales	...	...	...	29 to 56

In consequence of the profuseness of the iron sand deposits, and the facility with which the ore can be obtained, considerable attention has, from time to time, been devoted to the question of utilising them. Numerous experiments have been made, and large sums of money sunk in works, but hitherto without success. The metal cannot be produced in sufficient quantities nor at such a price as will in any way compete with the imported article. Furthermore, there is no immediate prospect of a different result; the subject has been thoroughly investigated in various parts of the world, and the unanimous conclusion is, that those sands, and other rich ores of a similar character, cannot be profitably reduced in quantity with the fluxes and appliances at present known. Under these circumstances it would not be wise to risk more capital in attempting to establish the manufacture in New Zealand.

The foregoing table gives the names of fifteen compact iron ores of New Zealand, about which some information has been collected. Of this number, four—Nos. 1, 2, 8, and 10—are in all probability unworkable. The extent of the deposit in the case of three—Nos. 4, 5, and 7—is unknown, and the supply of lime and fuel in the localities in which they occur is limited, consequently there is no immediate prospect of the ores being utilised. Four others—Nos. 6, 12, 13, and 14—are favourably situated as regards fuel and fluxes, but no estimate has been formed of the quantity of ore. This reduces the number of ores about which we have anything like positive information to three, viz., Nos. 3, 11, and 15.

No. 3, the Wakatipu Hematite, is found on the Shotover River, in a lode 6 feet thick. Both Dr. Hector and Professor Hutton report favourably as to the quality of the ore, the facility of obtaining fuel and lime, and the prospect there is of establishing ironworks in the neighbourhood.

Nos. 11 and 15, representing the two main classes of iron ores, occur in the Collingwood district, Nelson, within four miles of each other. No. 11 is the hematite or brown ore, already referred to, the supply of which is practically unlimited. No. 15 is probably the only genuine sample of black band ore yet discovered in New Zealand; it occurs in three distinct veins from 10 to 20 inches thick, the extent of the field being about 12 square miles. There is a plentiful supply of lime, timber, and

fire clay in the neighbourhood, and, according to Dr. Hector, the finest coal in the Colony is found associated with the black band ore. The coal is estimated at 50,000,000 tons. So far as explored, the seams are only from three to four feet in thickness, but they have every appearance of increasing.

All authorities are agreed in giving the iron ores of Collingwood a high place. Mr. Tatlock, Public Analyst for Glasgow, in a report to Mr. George Turnbull, of Dunedin, on the hematite ore, says:—"This ore is very rich in iron, and in this respect is equal to good Cumberland hematite, and even superior to the Spanish ores which are now used in the manufacture of Bessemer pig iron."

Some of the ore was sent to Melbourne and smelted; it made excellent iron. I have seen a sample tested alongside one of Lowmoor, and so far as could be judged by inspection, the Colonial product was the better of the two; it could be bent and twisted in all directions, cold, without breaking, and at the same time it did not seem to be excessively soft.

The Para Para ore is usually called "hematite," but it should more properly be placed in the next lower sub-division, named indifferently Limonites, Brown, or Bog ores.

In addition to the other advantages above enumerated, the Collingwood district has considerable facilities for shipping its products; so altogether it may be pronounced the most favourable place in the Colony for the establishment of the manufacture of iron. The Government is now advertising

in England and America for tenders for 100,000 tons of steel rails, to be manufactured within the Colony from New Zealand ores. I believe that this is sufficient to give the necessary impetus to a thriving and permanent industry.

The Para Para hematite ore has for years been extensively and successfully used in the manufacture of paint. Two factories have been in operation in Nelson, and their products are rapidly superseding the imported article. The native paint is giving unqualified satisfaction wherever it has been tried.

Copper.—Numerous specimens of copper ores have been found in New Zealand, notably in Otago, Nelson, and the Thames Gold Fields. Many of the economic ores have been discovered, but the information regarding them is by no means complete. The chemical constituents have, in most cases, been determined, but the extent of the deposits and facility for working them are practically unknown.

Copper mining has recently been commenced in D'Urville Island and Dusky Sound; the prospects are fair, but there has not been sufficient work done to warrant a decided opinion on the subject. Copper is found in Otago at Waipori, Tokomairiro, Clutha Valley, Carrick Range, and Moke Creek. The deposit in the latter case is described by Mr. Hackett as a true lode 18 inches thick, but Mr. Bradshaw reported it to be from three to five feet in places.

The New Zealand ores are generally copper pyrites—the one from which English copper is chiefly manufactured. They are also found in

gneiss and schist rocks, the matrix of the best ores in all countries. The English ores seldom produce more than 10 per cent. of metallic copper, and 6 or 7 per cent. pays to work in Cornwall. The New Zealand ores generally contain from 10 to 25 per cent. of metal.

The manufacture of copper is an expensive process, and the demand for the metal in the Colonies is limited, consequently there is no immediate prospect of successfully establishing smelting works. But the richness of the ore might warrant sending it to England in the raw state, particularly as the localities of some of the deposits present great facilities for shipping.

Lead and Tin.—Lead ores have been found in New Zealand in much the same localities as copper, and bars of the Colonial metal were shown at the Philadelphia Exhibition; still the information on the subject is very meagre. The character of the ore and the quantity of metal have in some cases been determined, but the extent of deposits are altogether unknown. According to Dr. Hector there is a vein at Collingwood two to five feet thick, but it is so intermixed with zinc ore that the two cannot be reduced separately. The greater number of the specimens hitherto found in New Zealand are of sulphide of lead or galena, one of the most useful lead ores.

Until about two years ago, no tin had been discovered in New Zealand, but at that time several specimens from the interior of Otago were sent to Professor Black for analysis. They were of the

variety known as "stream tin," which occurs in the form of round flat gravel on pebbles. In this case the sizes of the pieces ranged from that of swan shot to small bullets. The ore was supposed to have come from Waitahuna and Cardrona, but there is no information as to the exact locality nor the extent of the deposits.

Lead and tin are of much less importance in the constructive arts than iron and copper, still they perform useful parts, and as such demand consideration. Independently, however, of this, the work of reducing the ores is comparatively easy, so it might be made a reproductive industry in New Zealand if the raw materials were only obtainable in sufficient quantities.

THE END.

INDEX.

DUNEDIN: PRINTED BY COULLS AND CULLING, RATTRAY STREET.

TABLE II.

ANALYSES OF OTAGO LIMESTONES THAT FURNISH POOR LIMES, WITH ENGLISH AND FOREIGN TYPES.

Number.	Description.	Locality.	Lime and Carbonate of Lime.	Carbonate of Magnesia.	Silica Soluble.	Silica Insoluble.	Alumina Soluble.	Alumina Insoluble.	Sand Insoluble.	Clay partly Soluble.	Sesqui-oxide of Iron Insoluble.	Oxide of Iron Soluble.	Carbonate of Iron soluble.	Iron Alumina.	Insoluble Matter not determined.	Alkalies, Water, and Loss.	Analyst or Authority.	Remarks.	Number.
	English & Foreign Types.																		
1	Sandy stone of Calraic	France	70·00	...	2·00		1·25		24·75	...	...	...	...	...	...	...	M. Vicat	....	1
2	Coarse stone of Dessin	„	61·89	7·44	3·10		1·57		26·00	...	...	...	...	...	...	...	„	....	2
	Otago Limestones																		
3	Grey	Caversham	68·51	Trace	0·72	...	1·79	...	...	...	...	0·79	...	...	27·65	0·54	Dr Hector	Jurors' Reports, N.Z. Exhibition	3
4	Greyish yellow	Kaikorai	68·50		...	...	...	...	27·60	2·40	...	0·80	...	...	...	0·42	„	„ „ „ „	4
5	Dark grey	Waikouaiti	65·77	Trace	...	...	...	...	...	...	...	...	...	2·83	31·40	...	„	„ „ „ „	5
6	„ „	Upper Harbour West	64·60	1·16	1·00	...	3·00	...	...	...	...	Trace	...	...	30·01	0·22	„	„ „ „ „	6
7	Grey	Pleasant River	64·10		...	...	...	...	29·50	1·20	...	0·80	...	...	...	...	„	„ „ „ „	7
8	Bluish grey	„ „	63·08	1·10	0·63	...	0.60	...	...	...	...	0·83	...	...	29·53	4·22	„	„ „ „ „	8
9	Greyish yellow	Kaikorai	62·80		...	...	...	...	28·00	5·50	...	1·80	...	...	...	0·60	„	„ „ „ „	9
10	Light yellow	Waihemo	61·60	0·28	...	...	1·80	...	...	...	...	1·20	...	...	34·80	0.32	„	„ „ „ „	10
11	Dark grey	Kaikorai	60·86	1·99	1.57	...	2.90	...	...	...	...	1·78	...	...	30·19	0·71	„	„ „ „ „	11
12	Moeraki boulder ...	Moeraki	60·50	2.50	...	...	...	...	21·00	14·00	...	...	...	...	...	2·30	Dr Black	Laboratory Report, 1875-6	12
13	Bluish grey	Caversham	53·00		...	...	...	...	24·40	19·10	...	1·40	...	...	...	2·20	Dr Hector	Jurors' Reports, N.Z. Exhibition	13
14	Greenish grey	„	51·22	1·56	...	...	...	...	...	...	...	...	...	2·92	43·64	2·66	„	„ „ „ „	14
15	Bluish grey	Hawksbury	51·17		...	...	...	...	25·00	21·50	...	0·80	...	...	...	1·90	„	„ „ „ „	15
16	Compact dark blue ...	Wakatipu	50·79	2·80	0·23	23·58	8·84	7·49	...	...	1·56	2·80	...	...	...	1·91	Dr Black	12·46 per cent. of silica in form of sand	16
17	Dark grey	Hawksbury	50·05	1·70	0·70	...	2·94	...	...	...	...	0·90	...	...	42·94	0.77	Dr Hector	Jurors' Reports, N.Z. Exhibition	17
18	Fine grey, soft	Waihola	43·30	Trace	...	27·60	...	...	...	19·00	2·40	...	...	...	...	0·70	Dr Black	21·98 per cent. of silica in form of sand	18
19	Buff yellow	Kaikorai	42·10		...	...	...	...	21·00	29·30	...	1·70	...	...	...	5·90	Dr Hector	Jurors' Reports, N.Z. Exhibition	19
20	Dark grey	Tokomairiro	41·20	Trace	...	...	...	...	...	...	...	...	...	5·20	52·20	1·40	„	„ „ „ „	20
21	Pale yellow	Kaikorai	40·45	1·70	3·40	...	1·75	...	...	...	...	Trace	...	...	46·80	5·90	„	„ „ „ „	21

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TABLE III.

ANALYSES OF OTAGO LIMESTONES THAT FURNISH HYDRAULIC LIMES WITH ENGLISH AND FOREIGN TYPES.

Number.	Description.	Locality.	Lime and Carbonate of Lime.	Carbonate of Magnesia.	Silica Soluble.	Silica Insoluble.	Alumina Soluble.	Alumina Insoluble.	Sand Insoluble.	Clay partly Soluble.	Sesqui-oxide of Iron Insoluble.	Oxide of Iron Soluble.	Carbonate of Iron Soluble.	Iron Alumina.	Insoluble Matter not determined.	Alkalies, Water, and Loss.	Analyst or Authority.	Remarks.	Number.
	English & Foreign Types.																		
1	Shelly stone of Nièvre	France	88·00	......	6·85		4·00		...	......	......	1·15	......	...	......	......	M. Vicat	Feebly hydraulic; sets under water in 15 days	1
2	Aberthaw	England	86·20	......	......	...	......	...	...	11·20	......	......	......	...	......	2·60	Hy. Reid	....	2
3	Bituminous bluish grey	France	82·25	......	10·50		5·50		...	......	......	1·71	......	...	......	......	M. Vicat	Set under water in five days	3
4	Theil Limestone	„	81·36	1·00	......	...	......	...	...	14·90	......	1·70	......	...	......	1·10	Gen. Gilmore	Used in Port Said breakwater	4
5	Blue Lias of Lime Regis	England	79·20	......	......	...	......	...	...	17·30	......	......	......	...	......	3·50	Hy. Reid	Used at London Docks	5
6	High Falls stone	America	79·04		11·10		2·52		...	......	peroxide 1·42	......	......	...	......	4·54	Prof. Boynton	....	6
7	Yellow	France	77·40	......	13·25		8·35		...	......	......	1·00	......	...	......	......	M. Vicat	Eminently hydraulic; sets under water in three days	7
8	Metz limestone	„	77·30	3·00	......	...	......	...	...	15·20	......	manganese 1·50	3·00	...	......	......	C. Tomlinson	Eminently hydraulic	8
9	Lezoux	„	72·50	4·50	......	...	......	...	...	23·00	......	......	......	...	......	......	„	....	9
10	Blue Lias of Holywell	England	71·55	1·35	20·10		3·52		...	......	......	2·21	......	...	......	0·84	Dr. Muspratt	74·73 soluble, 25·27 insoluble } in acids. ...... Used in the Liverpool Docks	10
	Otago Limestones—																		
11	White conglomerate	Oamaru	87·08	Trace	not estimated	......	2·85	...	...	......	......	0·79	......	...	8·58	0·78	Dr Hector	Jurors' Reports, N.Z. Exhibition	11
12	Dark compact	Portobello	86·80	„	„	......	0·80	...	...	......	......	Trace	......	...	12·40	......	„	„ „	12
13	Dark fawn compact	Peninsula	86·05	2·22	0·20	7·00	0·90	3·57	...	......	0·55	0·97	......	...	......	1·46	Dr Black	3·17 per ct. silica in form of sand	13
14	Drab granular, 5th lowest seam	Dowling Bay	84·03	0·33	......	10·93	1·23	2·76	...	......	1·00	0·98	......	...	......	1·26	„	Trace of sand and mica	14
15	Fawn compact	Peninsula	82·03	Trace	0·36	9·10	2·30	2·53	...	......	0·55	2·80	......	...	......	0·33	„	2·67 per ct. silica in form of sand	15
16	Yellowish do.	Portobello	81·10	1·70	not estimated	......	Trace	...	...	......	......	0·60	......	...	16·60	......	Dr Hector	....	16
17	Fawn top seam	Peninsula	77·97	1·98	0·22	10·51	1·61	4·21	...	......	0·85	1·53	......	...	......	1·12	Dr Black	3·60 per ct. silica in form of sand	17
18	Drab granular, 2nd highest seam	Dowling Bay	78·87	0·80	0·62	12·70	1·52	4·05	...	......	oxide 0·70	0·35	......	...	......	0·39	„	3·80 per ct. „ „ „	18
19	Dark fawn. 3rd do.	„	69·70	1·50	0·31	18·87	0·80	3·74	...	......	0·69	1·30	......	...	......	2·09	„	7·60 per ct. „ „ „	19
20	Do. do. lowest seam	Peninsula	69·46	2·26	0·16	18·69	2·10	3·16	...	......	0·95	2·34	......	...	......	0·97	„	7·03 per ct. of sand, but mixed with some clay	20

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TABLE IV.

ANALYSES OF OTAGO CEMENT STONES WITH ENGLISH AND FOREIGN TYPES.

Number.	Description.	Locality.	Lime and Carbonate of Lime.	Carbonate of Magnesia.	Silica Soluble.	Silica Insoluble.	Alumina Soluble.	Alumina Insoluble.	Sand Insoluble.	Clay partly Soluble.	Sesqui-oxide of Iron Insoluble.	Oxide of Iron Soluble.	Carbonate of Iron Soluble.	Iron Alumina.	Insoluble Matter not determined.	Alkalies, Water, and Loss.	Analyst or Authority.	Remarks.	Number.
	English & Foreign Types.																		
1	Raw materials Portland cement	England	69·87	......	20·54		3·49		......	......	......	4·44	......	...	......	1·66	Various	....	1
2	Portland cement, artificial	"	68·11	......	20·67		10·43		......	......	......	0·87	......	...	......	......		Manufactured by White Bros.	2
3	" " "	"	62·00	......	23·00		8·00		......	......	......	4·00	......	...	......	......	Hy. Reid	Average quality	3
4	" " "	Germany	60·40		23·86		9·20		......	......	peroxide 5·12	......	......	...	......	1·92	Herr Feichtenge	....	4
5	Boulogne cement stone	France	63·60	......	......	......	......		......	23·80	......	......	6·00	...	......	6·60	C. Tomlinson	....	5
6	Portland cement, natural	Boulogne	65·13	0·58	20·42		13·88		......	......	......	......	......	...	......	......	Various	Quick setting	6
7	Calderwood cement stone	Scotland	71·30		8·80		3·40		......	......	protoxide 10·20	......	......	...	......	6·30	Prof. Penny	....	7
8	Vassy " "	France	63·80	1·50	14·00		5·70		......	......	......	......	11·60	...	......	3·40	C. Tomlinson	Quick setting	8
9	Rosendale " "	America	63·76		27·70		2·34		......	......	peroxide 1·26	......	......	...	......	4·94	Gen. Gilmore	"	9
10	Yorkshire " "	England	62·54		24·00		......	......	......	......	......	1·31	......	...	......	......	Various	....	10
11	Sheppy " "	"	61·40		18·00		......	......	......	......	......	5·25	manganese 6·75	...	......	......	"	....	11
12	Harwich " "	"	52·00	......	9·37		......	......	......	......	......	17·75	......	...	......	11·37	"	7·50 per cent. sulphate of soda, &c.	12
	Otago Cement Stones.																		
13	Septarian boulder	Moeraki	72·40	0·30	0·80	......	......	......	17·80		......	......	......	8·70	......	0·60	Dr Hector	Colonial Museum Report, 1870-1	13

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TABLE V.

TENSILE STRENGTH OF WAIHOLA LIME MORTARS WITH DIFFERENT SANDS.

No.	Description.	Locality.	Weight in lbs. required to tear asunder Bricks.	Remarks.
1	Grey, with faint yellow tinge; fine, but sharp.	Mr Knox's pit, Anderson Bay.	226 218	1½ sq. inches in middle not quite hard. 2 „ „ „
2	Grey; fine and sharp; small quantity of clay.	Railway cutting at English Church, Caversham	212 nil.	Good bed, uniformly hard. Broke in fixing; flaw in bed.
3	White; very soft, clean, and fine.	Railway cutting at Abbott's Creek	150 136	Uniformly hard throughout. „ „ „
4	Round quartz gravel.	Mr Cutten's pit, Anderson Bay	158 109	Uniformly hard throughout. „ „ but not all adhering.
5	Dark grey; irregular and soft.	Mr Casey's pit, Anderson Bay	143 122	2½ sq. inches in middle not quite hard. Thickish bed; soft in centre.
6	Yellowish grey; fine, very sharp.	Mr Knox's pit, Anderson Bay	143 67	2½ sq. inches in middle not quite hard. 2½ „ „ „
7	Quartz gravel.	Railway cutting at Abbott's Creek	140 82	Uniformly hard. Not adhering properly.
8	Reddish yellow, irregular; clay and quartz.	Railway Cutting at Abbott's Creek	138 88	Very thin good bed; uniformly hard. Bed not good.
9	Deep red; coarse; irregular.	Railway cutting at Abbott's Creek.	138 nil.	Uniformly hard. Broken on shelf.
10	Deep reddish yellow; fine and sharp.	Mr Cutten's pit, Anderson Bay	122 122	Piece in middle like a small oyster not quite hard
11	Orange; very soft and fine.	Railway cutting at Abbott's Creek	106 97	Not well set. „ „ „
12	Whitish grey; soft.	Mr Casey's pit, Anderson Bay	102 nil.	2½ sq. inches in middle not quite hard. Broken on shelf.
13	Yellowish grey; soft.	Mr Casey's pit, Anderson Bay	102 nil.	Not well bedded. Did not carry 28lbs.; seems to have been broken.
14	Greyish white; fine; very sharp.	Mr Knox's pit, Anderson Bay	96 nil.	Uniformly hard. Broke in handling; not adhering properly to bricks.
15	Reddish yellow; fine and sharp	Mr Casey's pit, Anderson Bay	88 nil.	2½ sq. inches in middle not quite hard. Did not lift 21 lbs.; not quite hard; not adhering well.
16	Grey; fine	Railway Cutting at Cargill Hill	82 68	Good bed; uniformly soft. „ „ „
17	Grey and yellow; fine	Railway cutting at Cargill Hill	82 nil.	Good bed; uniformly soft. Did not carry 28 lbs.
18	Greyish yellow; very sharp	Mr Harris's pit, Anderson Bay	81 70	Good bed; 3 sq. inches not hard. „ 5 „ „
19	Yellowish grey	Railway cutting at English Church, Caversham	75 nil.	Uniform consistency throughout. Broke in handling; not bedded.
20	Yellow; fine and sharp	Mr Harris's pit, Anderson Bay	67 nil.	2 sq. inches not quite hard. Would not stand handling.
21	Deep reddish yellow; fine and sharp	Mr Cutten's pit, Anderson Bay	65 nil.	Bad bed; soft in heart. Did not lift 28 lbs; piece like a small oyster not quite hard.
22	Deep orange; very sharp	Mr Cutten's pit, Anderson Bay	61 nil.	Very good bed; 4 sq. inches; not quite hard. Broke in handling.
23	Light orange; very sharp	Mr Cutten's pit, Anderson Bay	61 nil.	Good bed. Did not carry 28 lbs.
24	Yellow; sharp and fine	Railway cutting at Cargill Hill	54 nil.	Good bed; soft throughout. Did not carry 14 lbs.; bad bed.
25	Yellow; sharp and fine	Railway cutting at Cargill Hill	47 nil.	Pretty well set. Broke with about 10 lbs.
26	Yellow; mixed with pebbles as large as peas	Railway cutting at Abbott's Creek	nil. nil.	Broke in handling. Did not carry its own weight; soft throughout.
27	Yellow; fine and sharp	Railway cutting at Abbott's Creek	nil. nil.	Broke with its own weight. Do. do.; had not set.

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